242

ENGINEERING REPORT

RAPID TRANSIT FOR THE SAN FRANCISCO BAY AREA

PARSONS BRINCKERHOFF • TUDOR • BECHTEL

ENGINEERING REPORT TO

THE SAN FRANCISCO BAY AREA

RAPID TRANSIT DISTRICT

JUNE 1961

THE REPORT

PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS


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General Engineering Consultants To
San Francisco Bay Area Rapid Transit District
833 MARKET STREET
SAN FRANCISCO

June 20, 1961

San Francisco Bay Area Rapid Transit District
628 Flood Building
San Francisco, California

Gentlemen:

We submit herewith our Engineering Report, "Rapid Transit for the San Francisco Bay Area".

For the past two years we have been engaged in planning and estimating a comprehensive rapid transit system in the five counties comprising the District, based on concepts and standards that you have endorsed. We have studied transit methods, patronage, and operations, working closely with top experts in the transit field to develop engineering feasibility of the major system components. Many alternative routes were studied working in conjunction with representatives of local authorities. Sufficient typical designs have been made to develop an accurate estimate of the cost of the system.

These studies have culminated in the rapid transit system which is described and for which plans and estimates are presented in this report.

We appreciate the cooperation given us by the District board members and officials, its staff, and its other consultants. Bay Area authorities and agencies have been helpful, and the technical staffs of each city and county deserve especial recognition as do the Division of Highways, the Division of San Francisco Bay Toll Crossings, the Public Utilities Commission, the Golden Gate Bridge and Highway District, federal agencies, the railroads in the District, and a host of others. Utility com-

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panies gave generously of their time in determining utility relocation requirements.

We wish to acknowledge the important contributions made by our consultants, particularly Mr. Donald C. Hyde, General Manager of the Cleveland Transit System, who advised us on transit operations, and Dr. George W. Housner and Professor Frederick J. Converse, who advised us on seismological and soils problems in connection with the Trans-Bay Tube Studies.

It is our earnest conviction that a thoroughly modern rapid transit system is vital to the Bay Area as an indispensable element of the total transportation network. The concept and the cost of this facility are established herein, and modern technology can make possible the realization of its benefits to the San Francisco Bay Area.

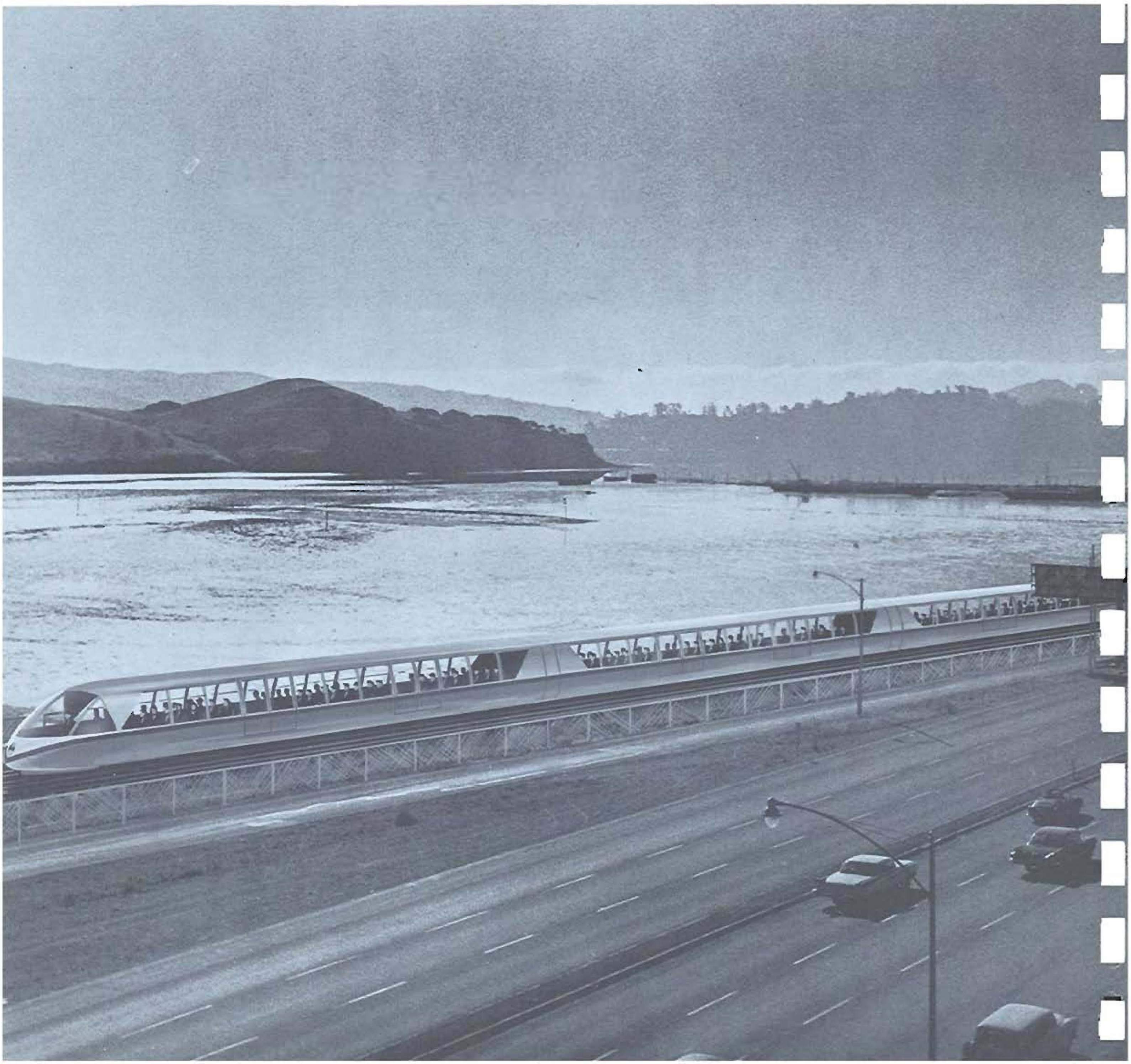
Very truly yours,

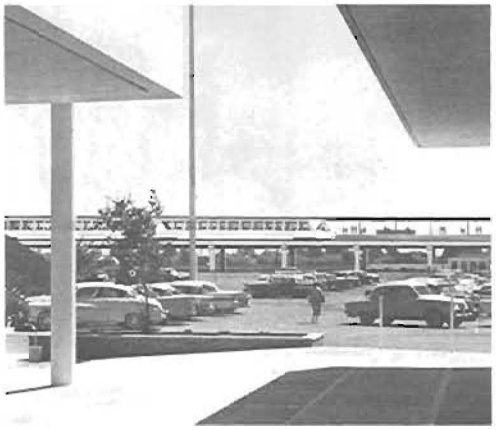
PARSONS BRINCKERHOFF-TUDOR-BECHTEL

Walter S. Douglas | Ralph A. Tudor | John R. Kiely

LIST OF PLATES

CONTENTS





SUMMARY

One of the provisions of the law that established the San Francisco Bay Area Rapid Transit District requires an engineering report that describes the facility to be provided, including an estimate of the cost and time required for construction and an estimate of the anticipated revenues. The rapid transit system developed as a result of the work done for the District on the mass transportation problems of this region is described in this report. Detailed plans and specifications must, of course, be prepared prior to construction, which will be in general conformity with the description of the facilities outlined herein.

Since 1959 engineering effort has been directed toward bringing before the electorate a comprehensive plan for express mass transportation for the counties of Alameda, Contra Costa, Marin, San Francisco and San Mateo. A series of preliminary studies were made over this period from which the plan described in this report was devised and used as a basis for development of the system and for the estimate of its cost. The proposed system will provide high-speed, frequent service along the major travel corridors of the five counties. Streamlined lightweight electric trains operating on their own grade-separated rights of way will speed people to destinations throughout the Bay Area.

The system is designed to attract and serve a maximum number of passengers. It will offer faster, more convenient, and more comfortable travel between central business areas and outlying residential areas than will be available by bus or private automobile, and fares will be competitive with the out-of-pocket costs of operating the private automobile. Trains will operate under the constant supervision of a computer-controlled system of automatic control designed to insure the highest degree of safety and service. In rush hours as well as in times of off-peak demand, trains will achieve average speeds up to 50 miles per hour including time for station stops. Maximum speeds will exceed 70 miles per hour.

Frequent service is important. A design objective is to minimize the waiting time for the greatest number of people and yet never to cause an excessive waiting time for anyone. At times of high traffic volume, train headways will be governed by demand; and over some routes, trains will operate as frequently as 90 seconds. During off-peak periods, except late at night, the frequency of service generally will not exceed fifteen minutes. Comfortable seated rides will be provided for as many as 30,000 passengers per hour in the peak direction of travel.

An automatic system of charge-account fare collection utilizing identification cards is designed for passenger convenience. Commuters will insert their cards in monitoring turnstiles at their origin and destination, registering the actual lengths of their individual trips. This information will be accumulated at a computer center and monthly statements issued on the basis of total travel during the period. Provisions will be included in the fare collection system to accommodate cash-fare passengers.

The rapid transit system is a two-track network extending approximately 120 miles throughout the Bay Area. The routes include about 24 miles of transit line underground and underwater, 52 miles at grade, and 44 miles on structure. Some 900 ultra-modern, fast, and comfortable rapid transit cars will serve the 52 stations located throughout the region.

San Francisco and Oakland are connected by the underwater Trans-Bay Tube beneath San Francisco Bay. From the San Francisco-Oakland-Berkeley central core area, five rapid transit routes will extend from 20 to 30 miles along the travel corridors. In East Bay, three rapid transit lines radiate to Richmond, to Concord and to Fremont. From San Francisco, the Peninsula Line proceeds south to Palo Alto, and the Marin Line crosses the Golden Gate Bridge and extends to Santa Venetia. Through densely developed business areas subway construction will be adopted. The trains will pass through the major hills in tunnels. Where feasible, the alignments of freeways, streets, and railroads will be used to keep generally within established corridors of travel and to reduce the amount and cost of private land takings.

Parking facilities are planned for over 40,000 private automobiles in the outlying areas where most passengers will usually ride to and from the stations. The rapid transit lines will traverse the central business districts and provide convenient service within easy walking distance for most of the passengers.

Careful analysis and research were devoted to the determination of patronage and revenues. Operating and maintenance costs were estimated in detail, using the experience of other transit systems where possible, but taking into account the unique characteristics of this proposed system. The results of these studies demonstrate conclusively that the system will earn sufficient revenue to pay all maintenance and operating costs and the debt service on the capital cost of rolling stock with reasonable margin. Revenue will not, however, be adequate to meet debt service on the capital cost of fixed construction.

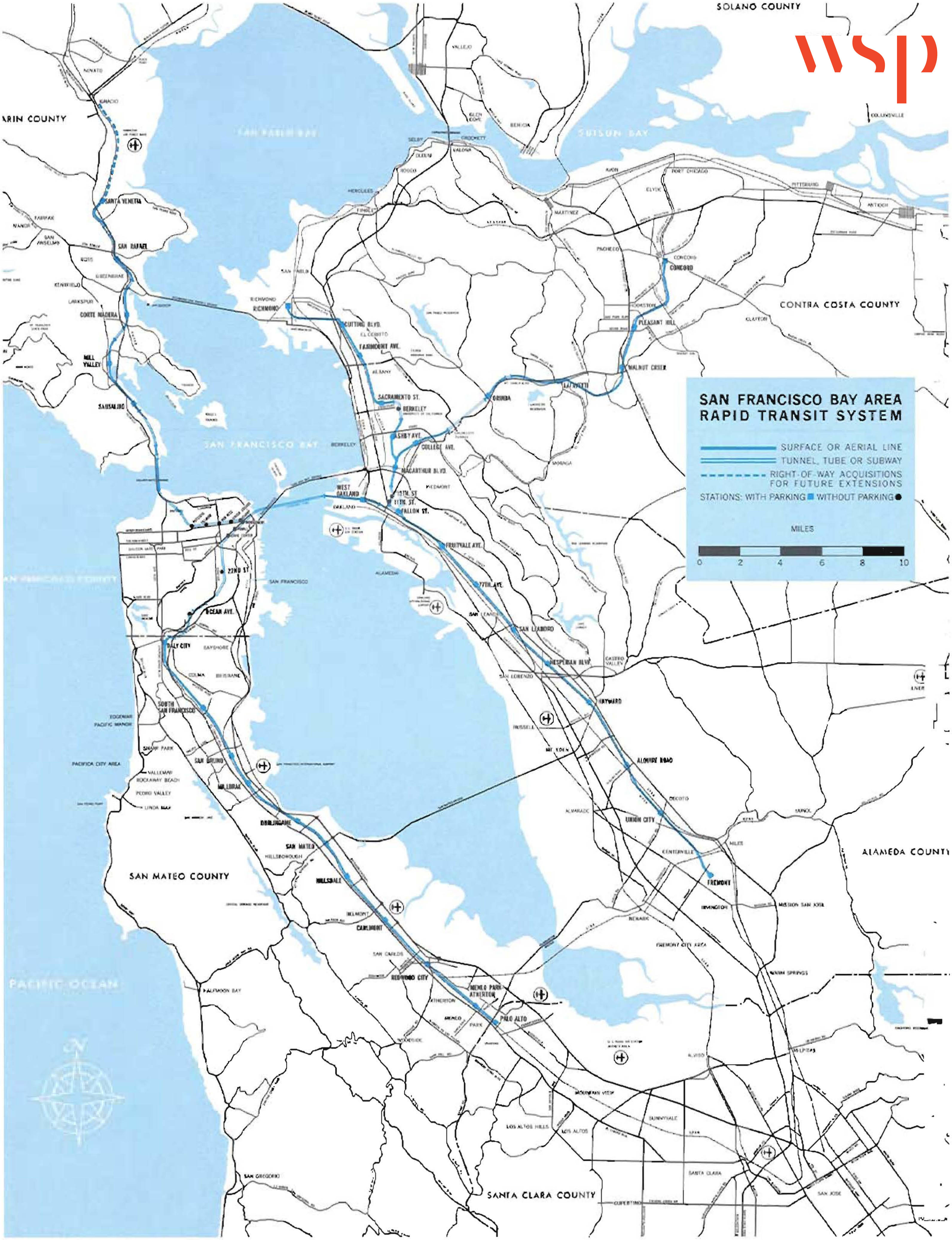
The capital cost of the rapid transit facilities, excluding rolling stock and financing cost, is estimated at $1,077,207,000. This includes a nominal amount to pay for certain necessary pre-operating expenses in a few early years of partial operation.

Sections of the system will be completed during the period of construction. These will be opened to traffic to provide service as early as possible and to begin collecting revenues. Because of these interim openings the benefits of rapid transit will be felt by the Bay Area early in the construction period.

In major metropolitan regions throughout the country, the need for greatly improved transportation facilities is becoming more acute year by year. Despite extensive existing facilities and active construction programs to provide additional street and highway capacity, severe congestion continues to increase on urban and suburban arteries of travel, particularly in peak periods.

No one mode of transportation can provide completely and economically for the movement of people. A balanced network of transportation facilities is essential. In the San Francisco area, grade-separated, modern, regional rapid transit will provide a necessary component in the total transportation picture. The proposed rapid transit system described in this report incorporates every desirable advance in modern equipment and methods and will successfully serve the regional mass transit needs of the Bay Area. Construction and operation of the rapid transit system conforming generally to the facilities described herein is feasible and can be accomplished within the estimated costs set forth.

THE SYSTEM


SAN FRANCISCO BAY AREA
RAPID TRANSIT SYSTEM
SURFACE OR AERIAL LINE
TUNNEL, TUBE OR SUBWAY
RIGHT-OF-WAY ACQUISITIONS FOR FUTURE EXTENSIONS
STATIONS: WITH PARKING WITHOUT PARKING
MILES
0
2
4
6
8
10
SOLANO COUNTY
MARIN COUNTY
CONTRA COSTA COUNTY
ALAMEDA COUNTY
SAN MATEO COUNTY
SANTA CLARA COUNTY
SAN FRANCISCO BAY
PACIFIC OCEAN
SANTA VENETIA
SAN RAFAEL
CORTE MADERA
MILL VALLEY
SAUSALITO
RICHMOND
CUTTING BLVD.
FAIRMOUNT AVE.
SACRAMENTO ST.
BERKELEY
ASHBY AVE.
COLLEGE AVE.
MACARTHUR BLVD.
WEST OAKLAND
19TH ST.
11TH ST.
FALLON ST.
FRUITVALE AVE.
77TH AVE.
SAN LEANDRO
HESPERIAN BLVD.
HAYWARD
ALQUIRE ROAD
UNION CITY
FREMONT
ORINDA
LAFAYETTE
WALNUT CREEK
PLEASANT HILL
CONCORD
22ND ST.
OCEAN AVE.
DALY CITY
SOUTH SAN FRANCISCO
SAN BRUNO
MILLBRAE
BURLINGAME
SAN MATEO
HILLSDALE
CARLMONT
REDWOOD CITY
MENLO PARK ATHERTON
PALO ALTO

BASIC CONCEPTS AND STANDARDS

The regional rapid transit system will form an important and integral part of the total transportation facilities of the San Francisco Bay Area. The networks of freeways, local streets, and local transit routes are all essential elements. By themselves, however, they cannot carry the entire mounting burden of traffic, particularly in periods of peak demand. Together these networks and the rapid transit system mutually complement each other and afford the Bay Area the best prospect for a balanced and economical combination of circulation facilities.

The Bay Area rapid transit system will abate motor vehicle congestion on the regional highways and in the urban centers, will encourage a continued high rate and type of economic development, and will preserve and enhance a high living standard. Rapid transit, as conceived in this system, will complement the private automobile as a mode of travel. At the same time, it must compete with the automobile. The relative attractions of rapid transit and the automobile, together with important considerations of public acceptability, were major factors in establishing standards for rapid transit methods, equipment, and operation.

The standards for rapid transit must insure a high level of passenger comfort, convenience, safety, and dependability; yet they must not be so high that they cause excessive costs which would threaten the financial acceptability.

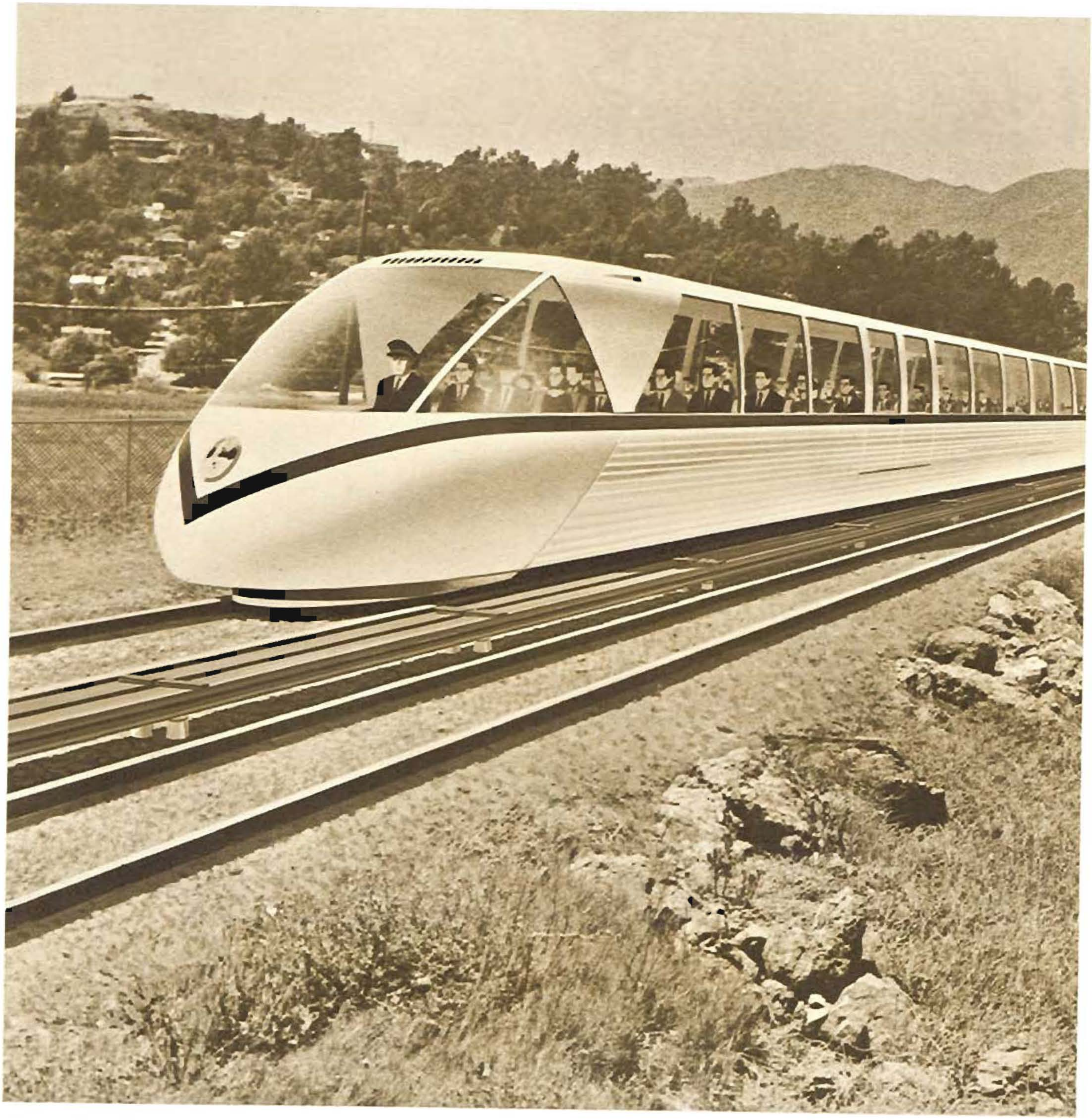
Some of the salient standards established for the rapid transit system with the objective of attracting patronage, particularly from the automobile travelers, are the following:

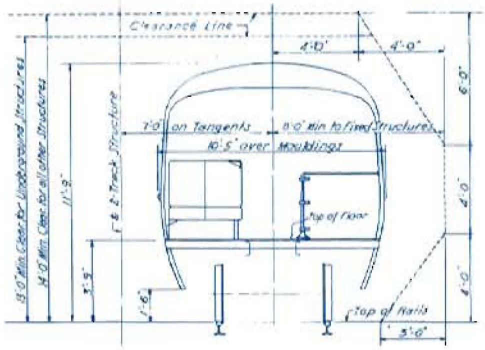
- Regional rapid transit must be capable of minimum average operating speeds of 45 miles per hour, including station stops. To achieve this minimum, the equipment must be capable of speeds of at least 70 miles per hour between stations and will in fact achieve average speeds of approximately 50 miles per hour generally throughout the system.
- Service during periods of peak travel should be governed by demand, with headways as short as 90 seconds. During off-peak periods, except late at night, service should be as frequent as every 15 minutes.
- The system must be safe and dependable.
- The rapid transit car must be comfortable with smooth riding qualities, internal temperature control, adequate ventilation, cooling and heating, sealed windows, freedom from fumes, a low internal noise level, and a pleasing internal and external appearance.
- The regional system must penetrate the major centers of business and commerce and provide distribution by a series of stations close to the ultimate destination of travelers to those centers.
- The system must achieve acceptance by the public generally, and by property owners particularly, along and near the right of way. Consequently, the equipment must have a low external noise level, and the system structure must be acceptable aesthetically.
- The adopted method of rapid transit must involve the minimum capital and operating expenditures consistent with these specified standards.

Speed and service standards require certain system and vehicle performance characteristics. These include high rates of acceleration and deceleration and high balancing speeds. To achieve these in turn requires easy alignment and minimum grades and complete grade separation of the rapid transit facility from all conflicting traffic.

The needs and desires of passengers during daily peak-travel periods will necessitate operation of trains with a minimum headway. The rapid transit system must be capable of carrying at least 30,000 seated passengers per hour in the peak direction, which requires train operation with a minimum headway of 90 seconds. The control of the trains must be reliable. Automatic train control by means of electronic computers and train-borne command sensors is an essential part of this system.

Stations must be conveniently located, but they must be spaced to be consistent with the high-speed regional-type service proposed. Stations that serve primarily as a residential collector facility must have adequate





and accessible parking facilities, including loading zones for vehicles waiting to pick up passengers, and for buses, automobiles, and taxicabs. The fare collection system must be convenient and expeditious.

ROUTE SELECTION

The location of the individual routes and stations of a regional rapid transit system is dictated basically by the requirements of the communities and the people to be served and the limitations imposed by topography and existing development. The patterns of movement of people and the location of job centers and areas of residence throughout the region serve as primary indicators of where rapid transit stations should be located.

Any recommended plan of routes, stations, and structures represents a balancing of the essential requirements of many interacting considerations. Among these considerations may be included the patterns of origin and destination of the person-trips of particular interest and affinity to regional rapid transit, economy of construction and operating cost, impact on the local community, aesthetics, and physical conflict with other existing and proposed developments.

The land use, traffic, and physical studies for the project have indicated clearly certain well-defined, high-volume regional corridors of travel within the Bay Area. The natural topography of the area results in a number of relatively long, narrow areas where people live and along which they must travel in large numbers in their weekday movements between home and work as well as for other purposes. Within each of these corridors a considerable number of alternative routes were studied, bearing in mind the controlling conditions just established.

In selecting desirable routes and types of construction in each area, the assistance of the local city planners and engineers was actively sought. Immeasurable assistance was forthcoming from these individuals who are most familiar with their own local problems and conditions. In many areas, as would be expected, there were differences in points of view. Where conflicting viewpoints persisted, one or more alternatives were studied and estimated for comparative evaluation. These alternatives and evaluations were presented to the San Francisco Bay Area Rapid Transit District in a series of engineering reports. Upon due consideration and consultation with all concerned, the plan which is generally described herein was devised and used as a basis for this report.

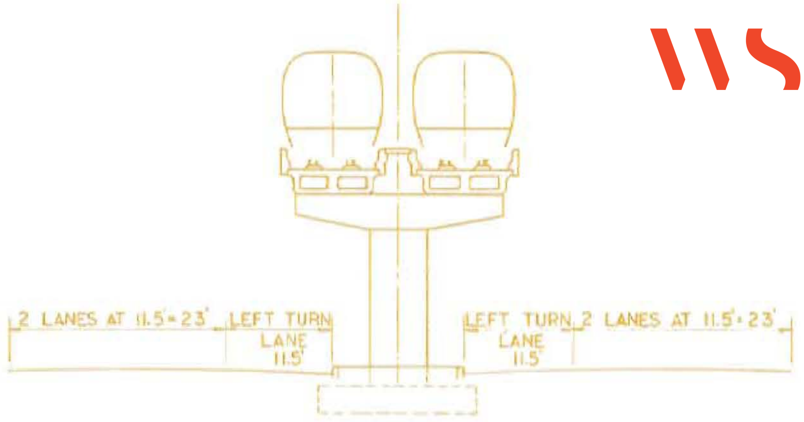
THE RAPID TRANSIT CAR

A basic feature in the development of a new rapid transit system is the evolution of the design of the car which transports the passengers. Basic concepts and standards have been established in order to determine, evaluate, and ultimately to select a satisfactory method and vehicle capable of transporting large numbers of people quickly, safely, comfortably, and economically. Requirements are generally described under Basic Concepts and Standards. The final design must reflect the full application of modern technology and style.

Performance specifications reflecting the standards previously outlined were sent to individuals and companies known to be professionally interested, and they were invited to submit transit proposals. Included were companies with records of accomplishment in transit car design, interested companies whose past work has been in other fields, and sponsors of several untraditional transit methods. Many useful and interesting proposals resulted, and some are still being received. This phase of the project study is being pursued continuously in the light of rapidly advancing technology.

Detailed proposals for lightweight, streamlined, but otherwise conventional rail cars were received from the Budd Company, and more generalized proposals were received from the St. Louis Car Company and the Pullman Standard Company.

The various proposals received for transit methods generally fall into two main categories; suspended trains where support and guidance are combined in a structure above the train, and supported trains where the supporting structure is beneath the train.



SECTION

Popular usage applies the term "monorail" to all suspended trains and to those forms of supported trains that appear to run on a single rail or beam. A true suspended monorail, however, where the car is hung from a single rail, is impractical for this high-speed system due to the uncontrolled sway of the car. Low maximum operating speeds are required to reduce sway to acceptable limits. The problems of switching trains at high speed from one route to another have not been solved, and this problem is inherent in varying degrees in most monorail systems.

A variation of monorail that holds considerable promise is the suspended duorail system, which is essentially an inverted narrow-gauge railway. A modern streamlined car body is suspended from rubber-tired wheel and motor assemblies, which travel within a track structure shaped like an inverted "U". The most active, current sponsor of this type of system is the Societe Anonyme Francaise D'Etudes, de Gestion et D'Entreprises (S.A.F.E.G.E. or French Monorail), which has developed a system and constructed an experimental installation now under operational testing near Paris. The duorail suspension permits application of a damping mechanism to restrict the sway to acceptable limits. Progress is also being made in solving the switching problem although the switching method does not yet equal the performance of conventional switching, particularly for yard operations.

The suspended monorail always requires an overhead support structure even when in tunnels, subways, and at grade. For underground construction, this increases the size of opening, and hence the cost. For aerial construction over streets where overhead clearance for vehicular traffic must be maintained, the required height of the structure considerably exceeds that of the aerial structure used for conventionally-supported trains. A significant portion of the proposed Bay Area system is at grade, and many of the future extensions will also be at grade, so that a structure would be required for monorail where none is required for the conventional system. An outstanding advantage of the conventional system compared to any monorail is its adaptability to any type of construction, and particularly its ability to operate on the surface when appropriate rights of way are available. Furthermore, when the transit line is alongside an existing surface railroad, suspended monorail would complicate the construction of overpasses for cross traffic.

In the basic supported monorail design, the train rides on a single "rail" or concrete beam. This beam is straddled by multiple sets of wheels running on the beam. Stability is obtained through horizontally or diagonally mounted wheels bearing on the sides or flanges of the beam.

From the standpoint of the pedestrian there is not a significant aesthetic difference between the structure for a supported monorail and that for a modern, conventionally-supported two-rail system. The method of switching involves a movable beam arrangement supported on a bridging platform. Switching capabilities thus far demonstrated have not been acceptable to the large-scale high-speed operations contemplated for the Bay Area, both on the main line and in the yards. Also, a structure consisting of beams and some type of supports is always required, and the method cannot take as full economic advantage of ground-level construction as can the conventionally supported system.

The supported form of monorail is now in public use to a limited extent. Familiar examples of this type of design are the Disneyland-Alweg monorail and the Alweg monorail now under construction in Seattle to serve the Century 21 Exhibition. Experimental sections have also been under test in Germany.

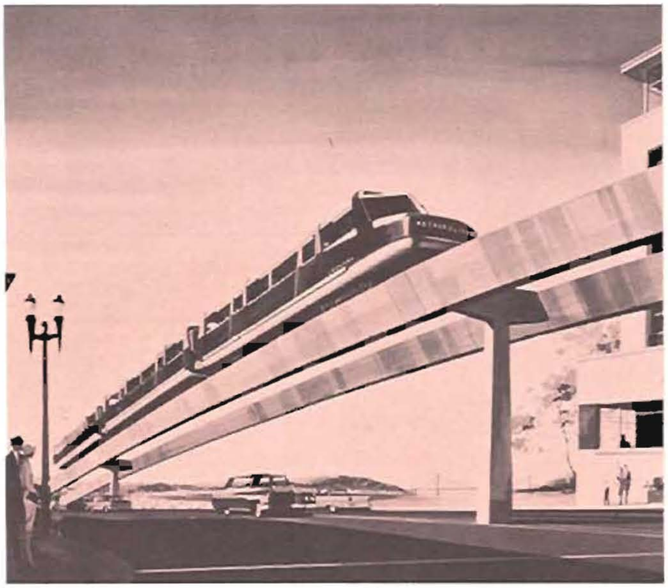
Among other transit proposals were several by aircraft manufacturers who were invited to study the design of the vehicle. Operating and capital costs of a transit system are direct functions of the weight of the train. It was felt that much could be gained from the demonstrated success of aircraft manufacturers in lightweight, attractive design, and with production techniques associated with the use of lightweight metals. Among the notable proposals received thus far are those from Lockheed Aircraft Corporation, Convair Division of General Dynamics Corporation, and North American Aviation, Inc. Research, development and test programs are required for certain aspects related to the car structure and truck design, but many basic techniques have been proven, and a substantial contribution to rapid transit design is indicated. The aircraft industry continues to show an encouraging interest in the development of a vehicle.

Among the proposals for truly untraditional and novel transportation systems were those using ground-effect vehicles, which ride on a thin cushion of air and on a guiding structure. Many firms have experimental air-cars in operation, but such a vehicle is quite noisy and requires much more power than a rolling-wheel vehicle of comparable capacity. The ground-effect vehicle is not considered to be developed sufficiently to be suitable for use in a mass transportation system.

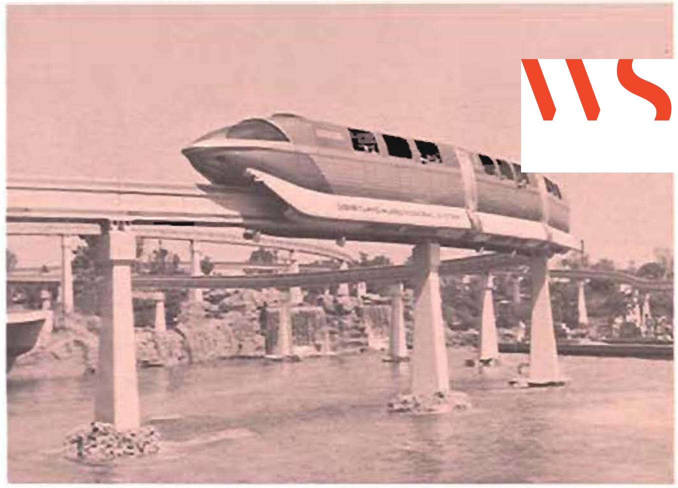
In the light of today's technology, the basic concepts and requirements set forth for the Bay Area system can be met by only one method of transportation that is proven. This method involves modern, lightweight, high-speed, stainless steel or aluminum trains, supported on steel wheels running on continuous steel rails, and operated by automatic train control. The adoption of this transportation method as a basis for the estimates in this report is not to present it as a final design nor to foreclose analysis and possibly ultimate selection of any different or untraditional method. Nevertheless, it should be emphasized that this is the only method which today meets all the essential requirements and which, in its basic elements, is thoroughly proven by actual test and operation. It is equally important to emphasize that modern developments and technology make possible a rapid transit system greatly contrasted to the awkward structures, noise, and other unpleasant characteristics of many existing and earlier transit facilities.

In considering the potential advantages and disadvantages of other possible methods of rapid transit, comparison can be made with this modern, proven sys-

Suspended duorail train — S.A.F.E.G.E. test track near Paris



Supported duorail train — San Francisco proposal by Lockheed Aircraft Corporation



Supported monorail train — Disneyland-Alweg design of Rapid Transit Systems of California, Inc.

tem, which becomes a measure for comparative analysis. Should any other transit method be adopted, that method should serve as well or better, and should be of equal or less cost.

The significant data relative to the car selected as the prototype include an overall length of 67 feet, 3 inches; an overall width of 10 feet, 5 inches; and a seating capacity for 76 passengers. The unloaded weight of the car per seat will be under 800 pounds. To achieve the required rates of acceleration each car is self-propelled. Power is supplied by third rail to electric motors driving each of the four axles. Deep skirts, constructed of inwardly curved sheets of stainless steel or aluminum, extend below the floor level on both sides of the car in order to minimize noise. Doors are of the sliding type, and the windows are permanently sealed. The roof, sides, ends, and floor are insulated, and the inside of the car shell is sprayed with sound-deadening material before the insulation is applied.

Short, efficient station stops require that the size, number and arrangement of doors and the width of aisles be adequate to permit efficient uncongested loading and unloading of passengers. This and the need for a comfortable seated ride are controlling factors in the layout of the car. To facilitate further service and station-stop efficiency, easy internal car-to-car circulation should be permitted. The passengers once they are on board the moving train, should have free access to cars with vacant seats. The seats and aisles, therefore, should be sufficiently wide, which in turn governs the car width.

The internal as well as external appearance of the rapid transit car should be attractive. Suitable ventilation and cooling and heating, freedom from fumes, and a low noise level are necessary for passenger comfort and satisfaction. Smooth riding qualities are essential.

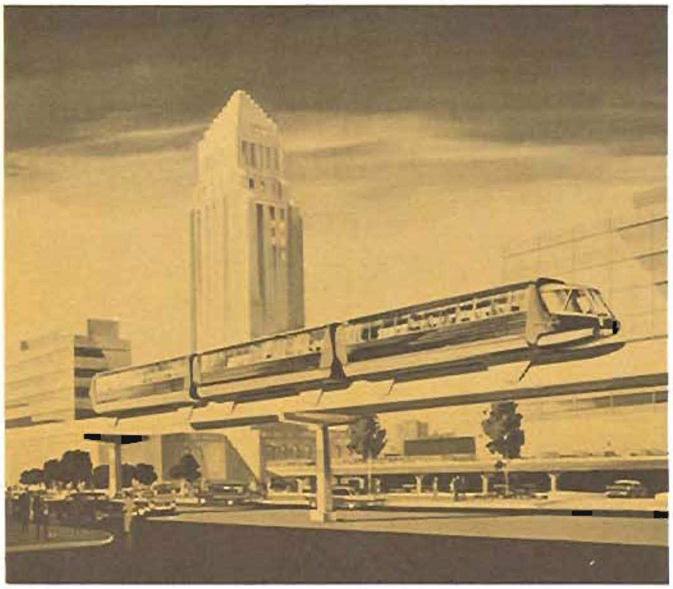
All of these requirements must be obtained in the design of a transit vehicle which is safe to passengers and employees. Consistent with the established standards the car must require the minimum outlay for capital costs of way and equipment and for costs of operating and maintaining the system.

POWER AND PROPULSION

The source and method of distribution of the propulsion energy and the design of the propulsion and control equipment are affected by the type of rapid transit car selected for the system. For any selected method of transportation, however, the propulsion equipment must meet the specified performance requirements, and the power supply must be efficient, reliable, and reasonable in cost.

Numerous methods of propulsion and power supply have been studied and evaluated in correlation with the studies of various transit methods. The power supply and propulsion equipment for the prototype conventional, two-rail, supported transit method have received primary study to explore and develop new technological methods and improved performance characteristics.

Power supply for a rapid transit system is usually direct-current electrical energy, often purchased from a local utility company as alternating current and then rectified to direct current. The basic energy source in this case is the coal, oil, gas, water power (hydroelectric), or nuclear fuel used by the utility company. Operation of trains in the subways and long tunnels of this rapid transit system precludes the use of gasoline- or diesel-engine powered equipment. Recent new and novel sources of energy, such as electrochemical fuel cells, were investigated and new developments in motive power were studied to determine whether a new source of energy might be utilized. While some potential does exist in the long-range future for the successful and economical application of some of these new



Supported monorail train — Los Angeles proposal by Lockheed Aircraft Corporation

Ground-effect train — "Airail" proposal for Los Angeles by Ideonics Corporation

energy sources, the use of bulk-generated electric energy is still the most practical, efficient, and economical method for today's application. Distribution and utilization of electrical energy, therefore, is the basis of design and estimate chosen for these studies.

Three main types of electric motors have characteristics more or less suited to traction applications. These are the polyphase alternating-current induction motor, the single-phase alternating-current series motor, and the direct-current series motor.

The polyphase induction motor is an extremely rugged, low-maintenance, and low-cost motor, and its control equipment is simple and of low cost. A significant advantage to this motor is the fact that three-phase alternating current could be purchased from the local utility company and utilized directly in the propulsion equipment without the necessity of providing rectifying equipment to convert the energy to direct current. The motor, however, is essentially a constant-speed machine, so that a torque converter or other speed-changing device must be interposed between the motor and the wheels. These additional transmission devices introduce complications that offset the advantages of the motor. Also, the problem of tranferring polyphase energy from the trackside to the moving car has not yet been solved satisfactorily. These problems are being comprehensively studied to find practical solutions that could enable the use of polyphase alternating-current power.

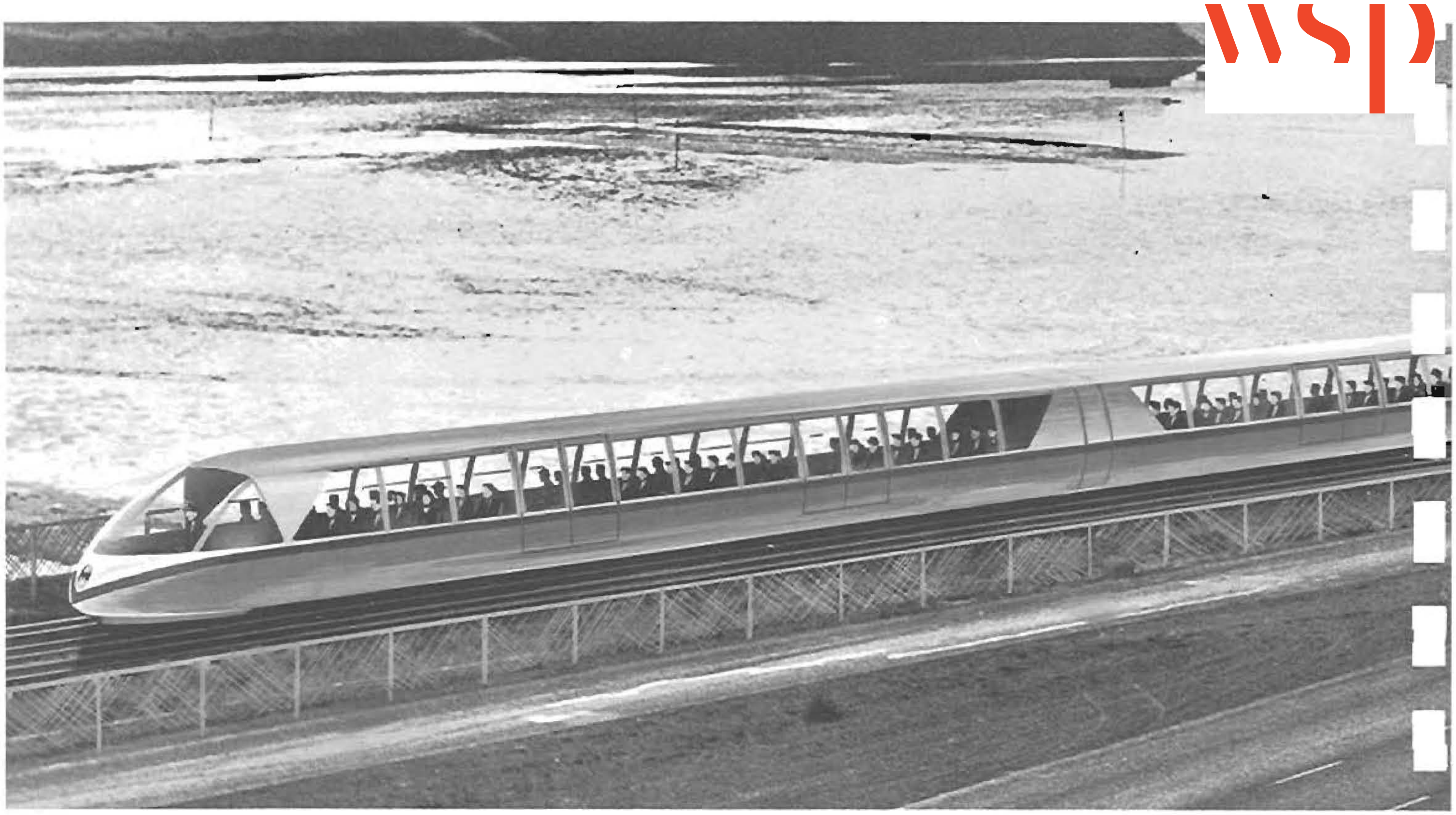
The single-phase series motor has been used in locomotive applications for many years, but it is being replaced by lighter-weight, more efficient motor-generator sets or rectifiers and direct-current series motors. The single-phase motor does not offer any advantage for the proposed system.

The direct-current series motor is the most widely used for transit purposes. Its design has been developed to a high degree of refinement, and it has the precise characteristics required for traction service. In its modern form, it is comparatively light in weight, rugged, compact and efficient, and requires a minimum of maintenance. While the control system for a direct-current series motor is relatively complicated, the control equipment is rugged and reliable.

The direct-current series motor and traction control establish standards of performance and efficiency that must be equalled or exceeded by any alternative method of propulsion and control ultimately selected. The alternative methods proposed so far have such limitations in performance, current collection, or size and weight that the direct-current series motor is the logical choice at this stage of the development as a basis for estimating costs. As is true with the car itself, the selection of direct-current propulsion equipment for present study and estimate purposes does not preclude ultimate adoption of a superior alternative should one become available prior to the time when final selection must be made.

Direct-current equipment normally is available in three voltage ranges: 750 volts, 1500 volts, and 3000 volts. The higher-voltage designs are penalized by greater weight and larger physical size, which are expensively reflected in the greater propulsion power requirements to drive the transit cars. Transfer of electrical power to the car is more hazardous and more subject to failure at the higher voltages; and dynamic braking, wherein the motor itself acts as a brake, is expensive and complicated to obtain.

Equipment designed for use on system voltages up to 750 volts is the most commonly used, and its design



is the most highly developed. This equipment is light in weight relative to its power capacity, it is small in physical size, and the required control equipment is reliable and low in cost. Dynamic braking is feasible without complication. Consequently, the lower-voltage equipment designed for the range of 600 to 750 volts has been chosen for this phase of the studies as the basis of design and estimate.

The proposed method of supplying power to the car from the trackside is a conventional third-rail system, whereby collector shoes on the car trucks slide on a power rail at the side of the running tracks. The third rail constitutes one electrical conductor and the other conductor, which is the return circuit, is composed of the running rails and paralleling copper conductors.

In the proposed system, the third rail is supplied with direct-current power at frequent intervals throughout the length of the system. Three-phase alternating current is purchased from the Pacific Gas & Electric Company at twenty-four locations in the system and distributed to trackside conversion substations which convert the alternating current to direct current and feed the energy to the third rail.

Many alternative power system plans and practices have been evaluated to develop a most reliable power supply. In areas where power interruptions would create critical situations, as in the Trans-Bay Tube for example, two independent third-rails and separate power supplies are provided so that a power failure is an extremely remote possibility. Throughout the system provision is made for the removal of equipment from service without interrupting the power supply to the trains.

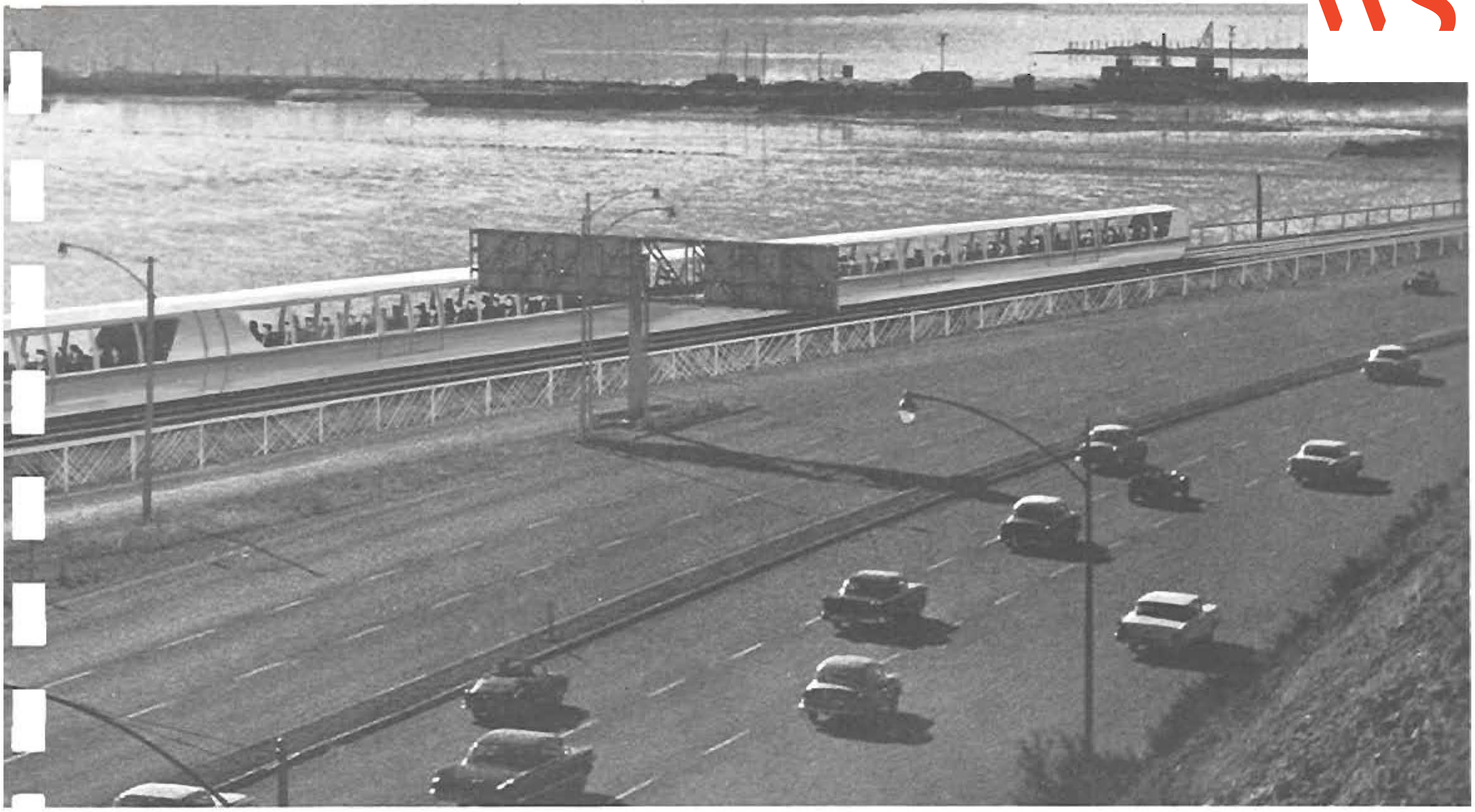
TRAIN CONTROL AND FARE COLLECTION

It is fundamental that the Bay Area rapid transit system include in its design a highly refined and fully integrated automatic control system. Passengers must be assured the highest degree of safe and reliable service. To achieve the specified high-speed, short-headway operation of trains over extended periods of time, normal train operation must be completely automatic.

The integrated control system provides all aspects of the control related to the identification and normal movement of trains, the overriding restrictive controls essential to safety, and the system-wide operational controls. These operational controls include the supervision of train locations and movements throughout the system, completely flexible communications channels, and supervision and accounting for a charge-account fare-collection system utilizing identification cards and monthly billing as a convenience to commuters.

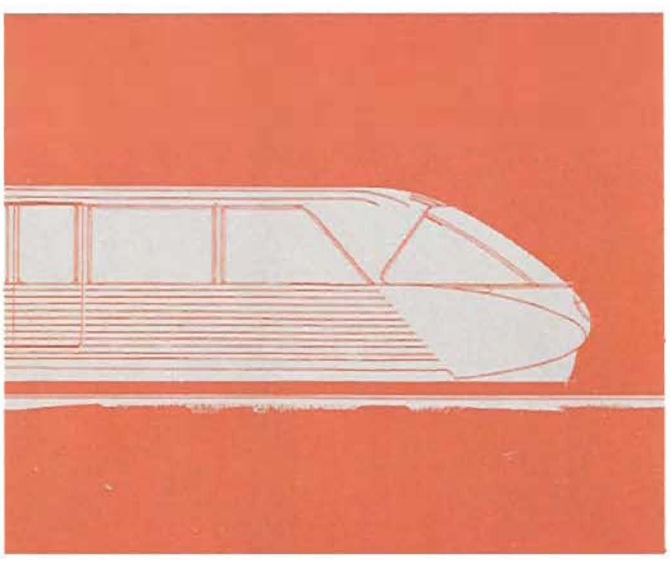
These broad areas of control and operation and their subdivisions customarily have been considered separate functions in transit operations. Their integration into a single system is probably the most significant development in this modern concept of rapid transit.

To achieve complete automatic operation of normal train movement, the control system must be capable of



performing the following functions:

1. Trains are started from storage points according to a dispatching program.
2. The travel of trains between stopping points is controlled so that they accelerate rapidly and operate on all sections of the route at the maximum safe speeds determined by topography, equipment performance characteristics, and other controlling physical conditions.
3. As a train approaches a station, its identification, arrival position, and destination are announced. The train is decelerated and stopped at a specific position within the station, the car doors are opened and closed, and the train is started on the next segment of its run.
4. Track switches at junction points are preset for the required routes depending on the identification and destination of individual trains.
5. A safe spacing of trains is maintained to prevent any train from overrunning another train.



In the design of all these control functions, the "fail-safe" principle of operation is observed to insure complete safety. The failure of any control element or the absence of a control signal when one should be present causes the train to react in a manner that is safe, even if it is necessary to stop.

Service to the transit passenger is considered to be more important than maintaining a time schedule of operations; thus, clock time is an operating factor only in determining when a train should depart from a terminal. The train accelerates and runs at its capability at all times except where restricted speed is necessary for safety reasons. The length of dwell time at a station stop en route is only sufficient to meet the needs of passengers entering and leaving the train, although the maximum time is limited to prevent excessive delay and overloading. In many respects the operation can be likened to that of an automatic elevator.

The make-up of each train is accomplished in one of the yards and is determined by traffic and patronage data accumulated in an element of the *central supervisory control system*. The time of day, weather conditions, current events, and other factors affecting the movement of people and traffic are evaluated to determine the frequency of dispatching of trains and the number of cars required in each train.

At the beginning of its run, the train is assigned an identification number that contains a coded designation of the number of cars in the train and its destination. This information is stored in the *train identification system* and is available to other control components along the route, which react, for example, to set turnouts for proper routing and to determine the proper stopping points at station platforms.

The *route control system* governs the movement of trains between stations. It transmits commands that are detected by sensors on the train and that control the acceleration, running speed, and deceleration to conform to safe, predetermined speed limits applicable to each section of track. A *block control system* performs a similar but completely independent control function of comparing train speeds and locations throughout the system. The block control system is capable of overriding all other forms of control, either manual or automatic, to cause a train to decrease speed or to stop should it approach too close to another train. Thus, a specific minimum spacing between trains is always maintained, maximum safe speed limits cannot be exceeded, and if a specific command is not received at all times, the train comes to a stop.

The *passenger station control system* assumes control of the train as it approaches a station. The train is identified and announced to waiting passengers and automatically brought to a stop at a predetermined position, depending on the number of cars in the train. The doors are opened and closed, the train is automatically started, and control is returned to the route control system.

The *train-borne control system* includes sensors that detect commands from the trackside or other locations. It also includes transmitters that convey identifying information to the trackside. As a received command is interpreted, the electrical controls of the train are altered as necessary to obey the command. Each train carries two units of train-borne equipment, one for each direction of travel.

The heart of the automatic control system is an industrial-type control computer, the central supervisory control. This computer monitors the operation of the entire system by constantly checking the location and movement of all trains, announcing abnormal conditions, adjusting the stopping time at stations to meet local requirements, and performing many other system-wide control functions. It also maintains a detailed log of the system and equipment operation, and serves as a link in the charge-account fare system.

A single attendant aboard each train visually monitors the operation of the train. The operating commands and the train performance are displayed on an annunciating panel before the attendant. He normally performs no function except to observe the annunciator and watch the track ahead for physical obstructions. The only overriding operating functions he can perform are to reduce speed or stop the train; he cannot exceed the limits set by the automatic control system.

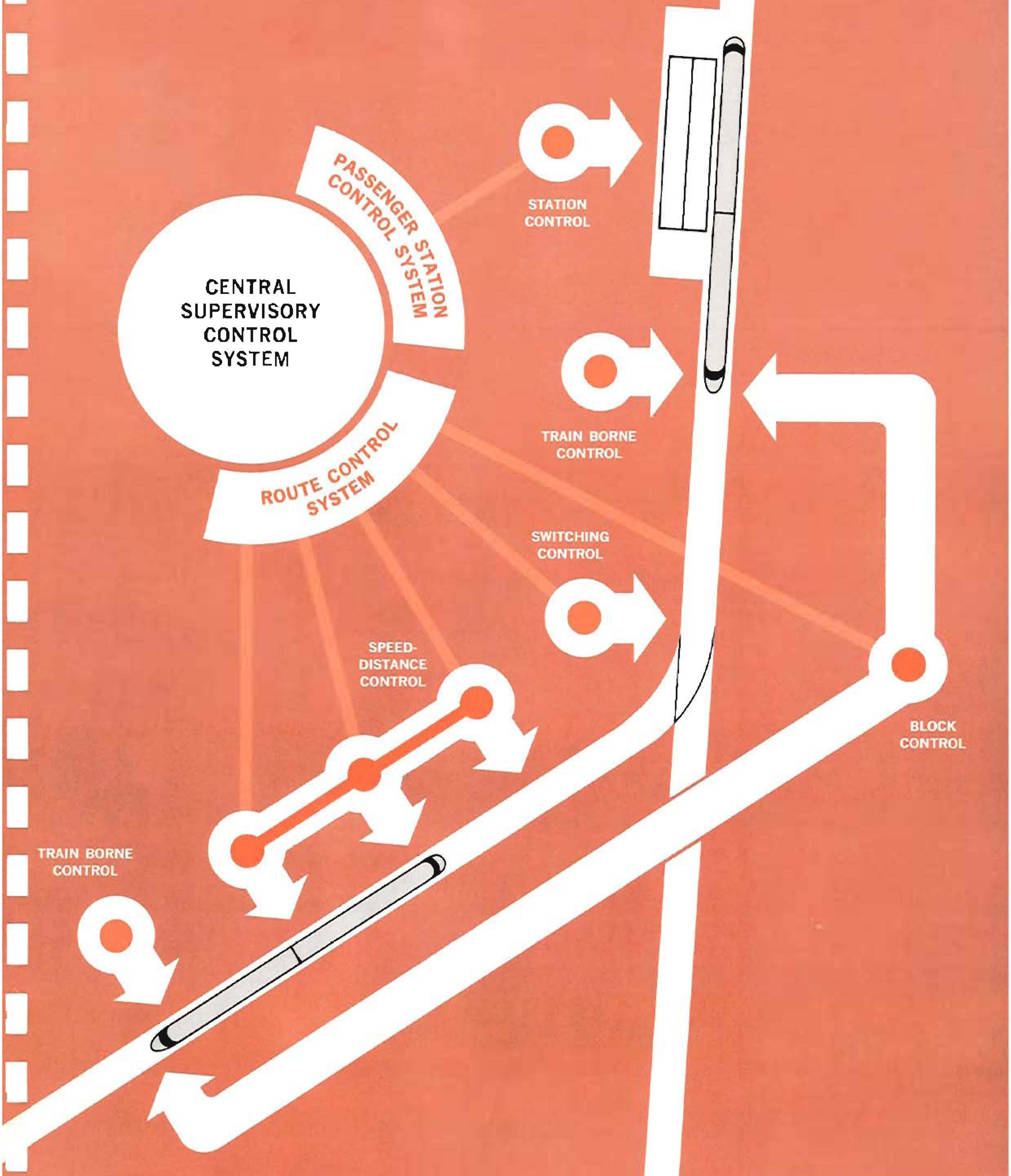
The integrated control system requires extensive channels of communication for its supervisory functions. These same channels can be used to provide completely flexible voice communications. For example, the central control supervisor can communicate directly with the attendants and passengers on all trains in operation and with personnel in passenger stations and yards.

The flexibility of control and communications afforded by the automatic control system concept leads directly to the incorporation of an automatic charge-account fare collection system designed particularly for the convenience of the regular commuter.

As discussed in the section on Patronage and Operations, the fare structure adopted for the Bay Area system is unlike that used on existing rapid transit systems, in that the fare is a direct function of the mileage travelled. This increases the difficulty of automatic cash-fare collection from the occasional rider, but the use of an identification card can be accommodated automatically without difficulty.

The standards of operation of the fare collection system are correlated with the standards established for

AUTOMATIC TRAIN CONTROL CONCEPT



the entire transit concept. Large numbers of passengers must be accommodated without delays, and the fare collection operation, whether cash or credit, must be simple, convenient and accurate.

For the cash-fare passenger, change is available from change-making machines, capable of handling paper money as well as coins, or from a station agent. The correct fare for the trip is deposited in a turnstile and the passenger receives a token indicating the boarding point and the fare paid. At his destination, the token is deposited in an exit turnstile, which determines whether the correct fare was paid.

The charge-account passenger inserts his identification card in the turnstile, which records his identification and boarding point. A similar operation at the exit turnstile records his destination. This information is sent to the central digital computer, correlated, and the fare is added to the rider's charge account. Once each month the accounts are reconciled and statements issued automatically for mailing to the patron.

The charge-account system with its automatic recording and billing offers simplicity and convenience for the passenger and greatly reduces the problems and expense of change making and token handling. This method of charging for service is expected to encourage and retain patronage for the rapid transit system.

While the automatic control and charge-account systems conceived for the Bay Area rapid transit system are not in operation elsewhere, the basic designs are developed to the degree where feasibility is unquestioned. Several potential manufacturers have offered proposals. Many of the system components are in actual operation in industrial control systems, and several railroads and transit systems are testing and experimenting with limited forms of automatic control. The development of a completely new rapid transit system offers the opportunity to incorporate these new concepts to the fullest possible degree.

TRANSIT STRUCTURES

In developing the routes, three basic types of construction are utilized — surface or on-grade construction, elevated or aerial construction, and underground construction. All three, and any modification of these, must provide an assured grade-separated right of way.

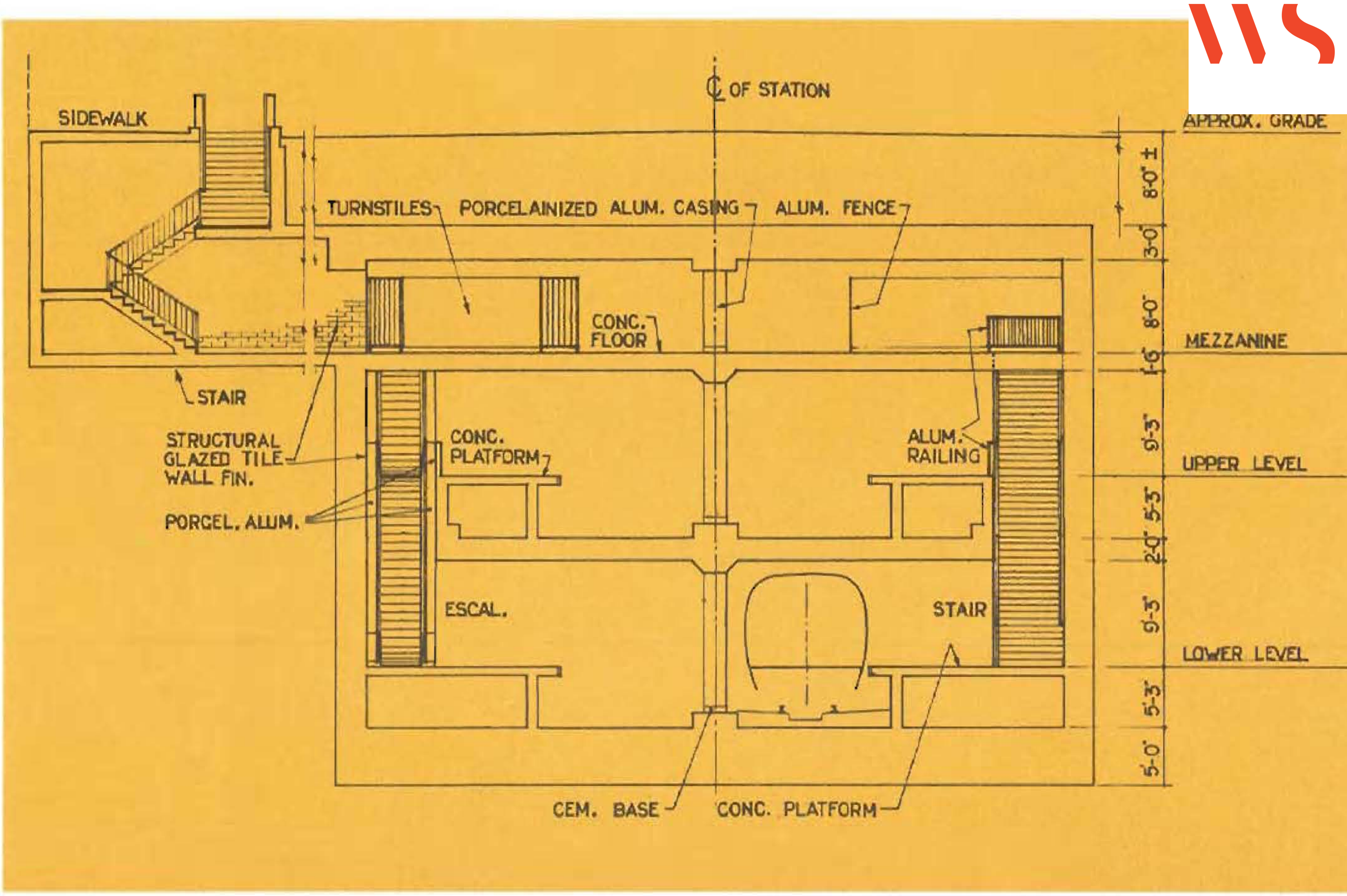
The rapid transit facility can be constructed on grade close to the ground surface, where appropriate rights of way are available or are attainable reasonably. This type of construction is often least expensive, the stations are most readily accessible, and it is unobtrusive and blends with the surroundings. Traffic crossing the rapid transit tracks must be on overpasses or underpasses, however, and when frequent grade-separation structures are required, the total cost of on-grade construction may increase greatly. Surface construction is proposed alongside existing railroads, on abandoned railroad rights of way, on median areas of freeways, and on rural private rights of way.

Depressed or open-cut construction is a modification of on-grade construction. The transit facility is placed in an open excavation, of partial or full depth, which often permits construction of ground-level overpasses to serve cross traffic. Another variation is the placing of the facility on fill. This, too, interrupts cross traffic which then must be carried through underpasses beneath the transit line. The right of way width required for these two methods is usually much greater than that required for other methods of construction.

In aerial construction the transit facility is placed on narrow elevated structures, making virtually unlimited circulation available for cross traffic. Aerial construction is considered acceptable in streets having a minimum width between building lines of 100 feet. This provides separation of the transit structure from adjacent buildings and results in a light, shadow-free thoroughfare for the pedestrian and the property owner. Aerial structures are located in the center of wide streets, on boulevard median strips, alongside railroads and freeways, and on private rights of way.

Underground construction is the most expensive and is utilized only where physical barriers necessitate it, or where above-surface space is not available for transit or is prohibitively expensive. Underground construction affords practically unlimited vehicular movement over the rapid transit tracks.

In underground construction, a distinction must be



made between subways and tunnels. As applied to the transit system a subway is an underground railway involving stations accessible from the surface, and it is most usually under an urban street. A subway makes possible the direct delivery of passengers to densely built-up and congested downtown centers. A tunnel, on the other hand, is a continuous underground passage through or under a physical barrier, such as the tunnel through the Berkeley Hills or the underwater crossing of San Francisco Bay.

Tunnelling construction methods can be used in certain areas of subway construction, usually those that are very deep below the surface. When tunnelling methods are used for subway construction they tend to minimize street interference, except at ventilation and construction shafts and at stations. Conventional subway construction, however, results in station platforms closer to the street level, and hence more convenient to passengers.

Development and research are continuing on advanced methods of subway construction. Special means of soils solidification and shallow-depth tunnelling are under study and could conceivably reduce materially the difficulties of urban subway construction.

All structures are designed for the loadings produced by a car designed to the specified standards by leading car manufacturers. For other forces, for combinations of loads, and for unit stresses, the American Railway Engineering Association's design specifications were used. Forces due to earthquakes are assumed to be equivalent to a horizontal force of one-tenth the vertical load applied at the centers of gravity of the component parts of the structure. The technical design standards and specifications are consistent with current railroad, street railway, tunnel, and subway practice. The specifications of the American Railway Engineering Association have been used as a guide along with those of the American Association of State Highway Officials. The General Orders and Regulations of the California Public Utilities Commission have been followed where applicable. The clearance diagrams have been reviewed by the California Public Utilities Commission.

ON-GRADE CONSTRUCTION. Although not a structure in the usual sense, on-grade construction is extensively proposed in this system. For the purpose of obtaining a basic estimate, a typical design was prepared generally along conventional lines. It incorporates the most modern devices such as shock-absorbing resilient pads, special rail connections, and continuous welded rail, and is considered thoroughly adequate for high-speed, trouble-free, quiet operation.

Work is continuing on the development of a special concrete roadbed for the track. This may offer advantages of lower maintenance costs and of further improvements in riding qualities.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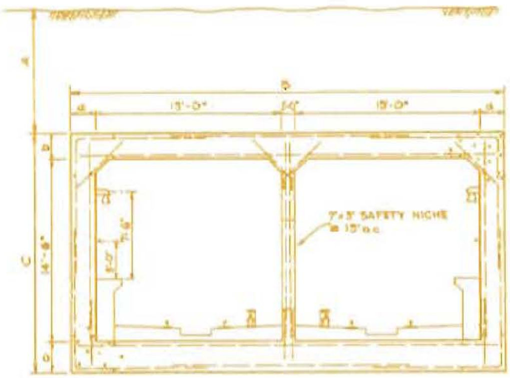


TWO TRACK - ONE LEVEL

Aerial Structures. Each span of the typical structure consists of precast, prestressed concrete box girders. Pier caps are of precast concrete, and the piers and footings are of cast-in-place concrete.

Detailed design computations were made for complete structures entailing several different typical spans with various column heights and foundation conditions. Quantities of construction material were computed for each of these typical designs. These designs were then applied to the respective routes, taking into account the variations in span length, heights of structure, foundation conditions and curvature required by the actual physical conditions encountered.

To control the noise level of train operation, special parapets are provided in the superstructure. A sound-deadening surface is provided on the inside face of each parapet to limit the reflection of sound waves.

Subway Structures. Construction procedures for underground structures have been established and improved through many years of experience and precedent. The design of the subway structure was developed after detailed consideration of the experience of several operating transit systems in the United States, Canada, Europe and Japan.

For purposes of the estimate, cut-and-cover construction is utilized. Under this method sections of street are excavated to minimum working depth, the cut is then decked, and the street is restored to traffic while work proceeds below.

In some areas the track profile is sufficiently deep so that tunnelling methods are advantageous. In these areas, particularly where it can be done under normal air pressure, tunnelling is utilized.

The choice of concrete or steel for the construction material has usually been a question of relative cost at the time of construction, and both materials have been used in recent subway construction. Based primarily on the cost advantage recently prevailing in the San Francisco Bay Area, concrete box sections were selected for the subway structures.

To provide a good basis for estimating the subway structures, designs were developed for the many different typical sections, with varying depths below grade and with varying ground water conditions. Detailed quantities were computed for each case and the sections adapted to the actual conditions encountered.

Tunnels. Tunnels for the transit system were designed by adapting modern conventional tunnel construction practices to the existing subsurface conditions in the Bay Area. The designs were developed after careful review of the construction history of numerous tunnels driven through similar geologic formations. In this phase of the studies, extensive drilling, geophysical surveying and detailed geologic mapping programs were not undertaken; but a reconnaissance of each tunnel alignment was completed and existing geologic information was evaluated.

Three basic designs of tunnels were adopted, designs were detailed, and cost estimates were developed.

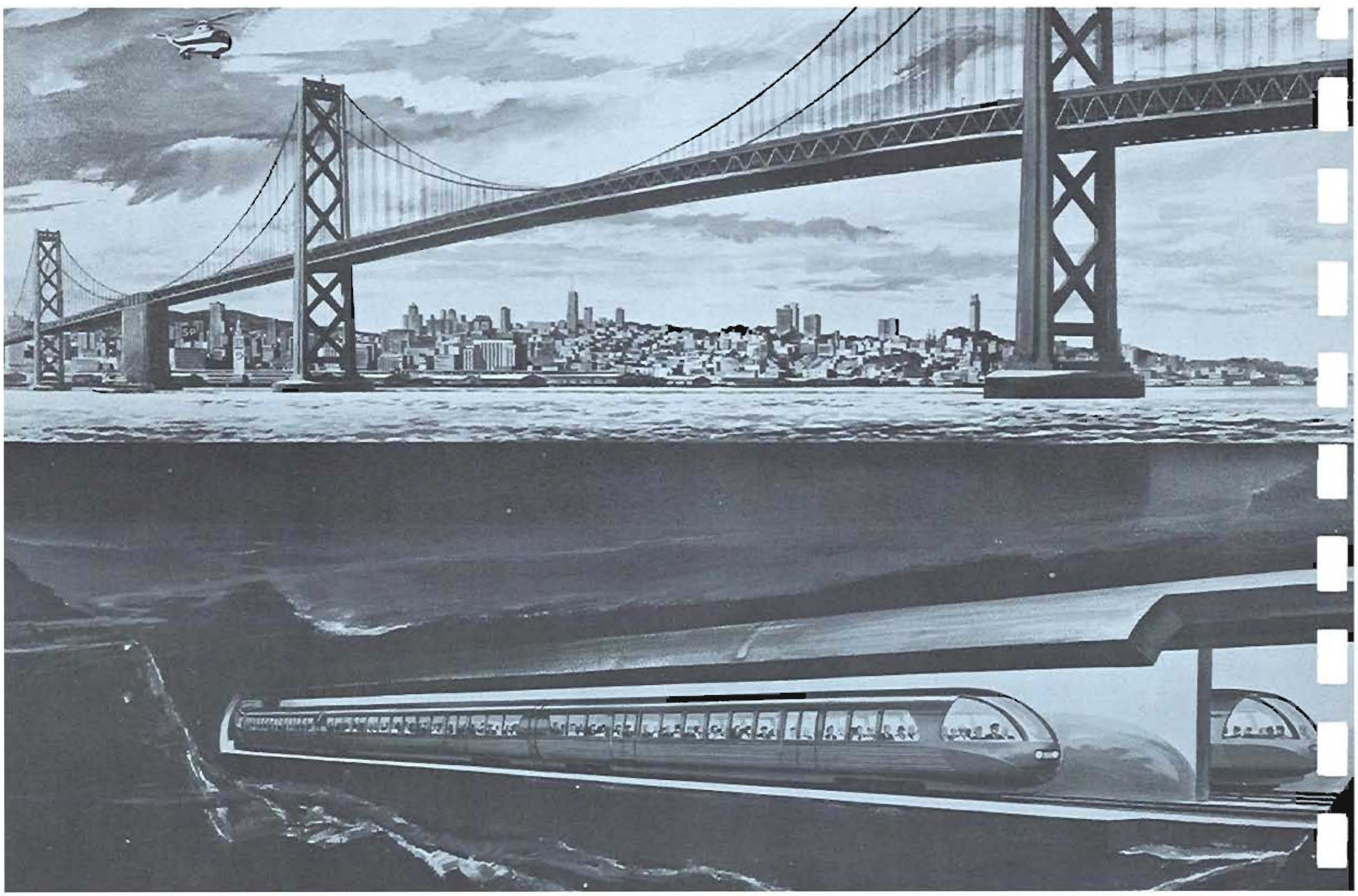
The first of these designs is a double-track, horseshoe-shaped tunnel designed for average ground conditions in the area. This design should be adequate for many of the proposed tunnels.

The second is a design that consists of two 15-foot wide single-track, horseshoe-shaped tunnels. This tunnel is designed for use in areas where moderately heavy support is anticipated and tunnelling conditions are expected to be difficult.

The third design is based on extremely difficult tunnelling conditions where the maximum amount of support is essential. This design consists of twin 15-foot diameter circular tunnels.

The Golden Gate Bridge. The technical feasibility of placing the rapid transit facility on the Golden Gate Bridge was most recently studied by C. H. Gronquist, Consulting Engineer of New York, N. Y., and a report of the structural and aerodynamic findings was submitted to the District on March 15, 1961. We concur in the conclusions therein stated.

With respect to the suspension portion of the bridge, Mr. Gronquist found that the bridge can accommodate the planned rapid transit with complete



safety and with minor modification to the structure. In the proposed design the trains occupy the space beneath the main deck of the bridge and above the lower chord of the truss. The appearance of the bridge is virtually unchanged.

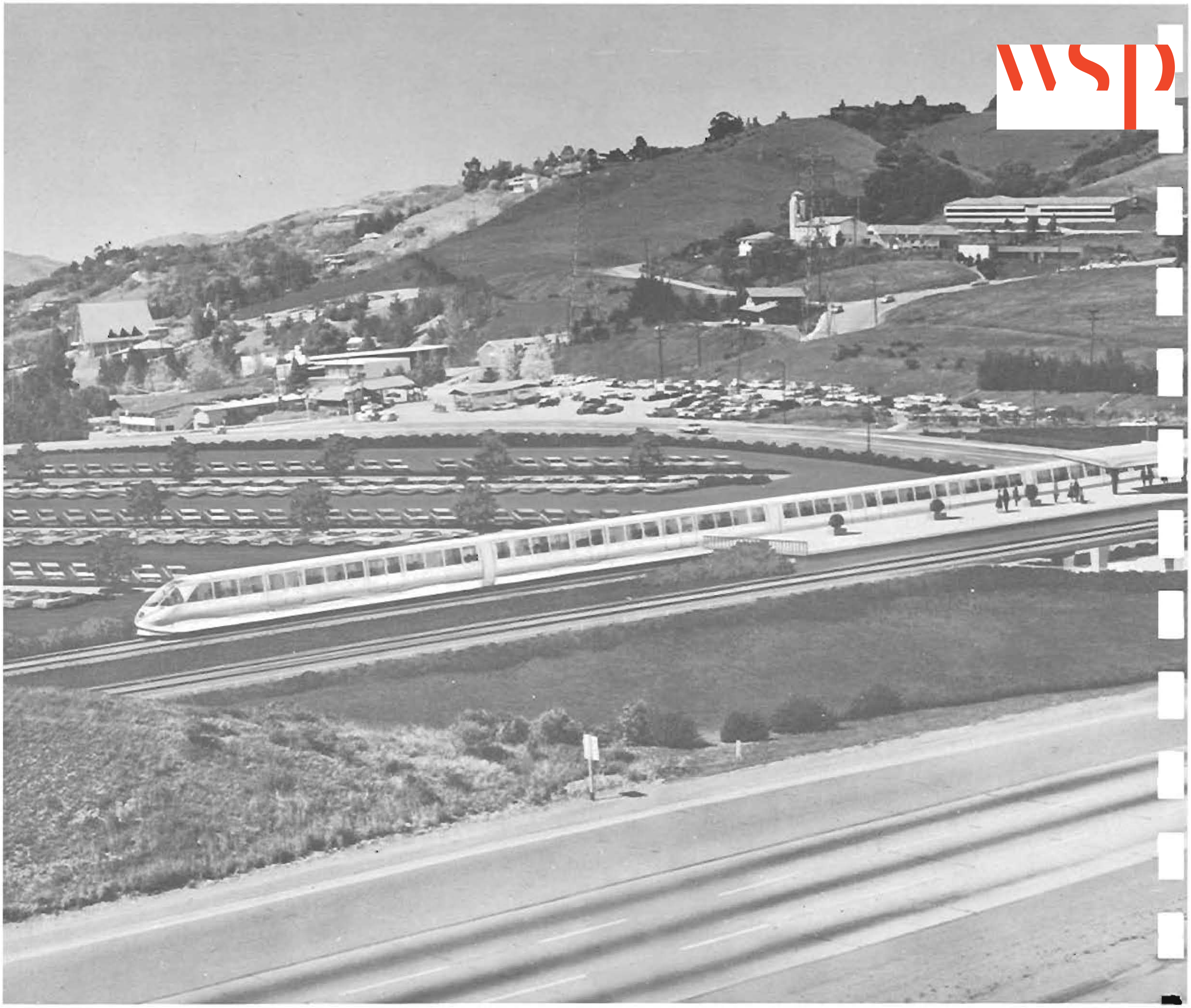
Supplementing the work pertaining to the suspension bridge, studies were made of the north and south approaches to the bridge by Parsons Brinckerhoff-Tudor-Bechtel. Throughout these approaches, rapid transit is located to the maximum extent possible on independent new structures. Alterations are required to some of the bridge approach spans adjacent to the main suspension spans to accomplish the transition from the alignment on the main spans to an independent alignment on the approaches. A preliminary design of the required alterations and of the additional structures was made and cost estimates developed.

The Trans-Bay Tube. Successful techniques have been developed for the construction of tunnels for underwater crossings as attested by numerous existing structures. Except for provisions to account for the effect of earthquakes on an underwater structure, standard design procedures for sunken-tube construction were used for this subaqueous tunnel.

In order to evaluate the earthquake effects, a limited number of exploratory test borings were taken from the bottom of the Bay to study the transmission of earthquake shocks through these soils. Electrical instruments designed to detect ground movements were installed in the Bay bottom and connected to an earthquake recording system as part of a long-range program to study the relative effects of earthquake vibrations in the Bay mud compared with those in the underlying bed rock. This program and the analyses of stresses were performed in collaboration with Dr. George W. Housner and Professor Frederick J. Converse of the California Institute of Technology, consultants in connection with the study of earthquake effects.

A prior report was prepared by Parsons Brinckerhoff-Tudor-Bechtel for the District in July 1960, entitled "Trans-Bay Tube Engineering Report", and it contains a detailed discussion of the design, construction and alignment of the tube. Our principal observations and findings are:

- Construction of the Trans-Bay Tube is entirely feasible from the engineering standpoint.
- Stresses induced in the tube by earthquakes are not of sufficient magnitude to exert a controlling influence on the design of the structure.
- Use of a precast concrete tube with metal shell for the underwater crossing between shore points is recommended.
- Use of a twin shield-driven tube for the San Francisco approach into Market Street will reduce street



interference and disturbance to the Ferry Building.

■ Cut-and-cover construction in a braced trench should be used for the Oakland approach into the Oakland Mole.

STATIONS

The regional rapid transit system transports people between outlying suburban areas and the central core areas, and the transit stations are the points where the passengers gain access to the system. Those stations in the suburban centers usually collect passengers from large residential areas, and it is necessary that loading and parking provisions be made to handle local feeder facilities such as buses and private automobiles. Stations in downtown districts deliver passengers generally within walking distance of most business centers, which are the destinations of the majority of the passengers. At these stations, parking facilities are not required. The design of all stations must be such as to serve the peak movement of people without congestion and without delay.

At those stations where parking is required, the station site includes one or more paved, lighted, and landscaped parking lots. These stations also have access lanes for local buses, taxis, and waiting automobiles.

At the time of final design each station must be detailed to fit its specific site, purpose, and flow of patrons. At this present stage of the studies, typical station designs are considered adequate. Typical stations were designed to coordinate with the typical structures of the foregoing section; quantities were determined; and estimates were made. These typical designs included

on-grade, aerial, and subway stations—for all the various combinations of number of tracks, platform types, mezzanine arrangements, and single and multi-level stations.

Both the surface stations and the aerial stations are planned with roofed cover for one-half the length of platforms. Entrance and fare collection facilities are on one side of the surface stations with connection to the other side by means of pedestrian underpasses. The aerial station provides entrance and fare collection on the ground level beneath the station structure, and the subway station has its entrance and fare collection facilities on the mezzanine level above the tracks.

Platforms at the car-floor level are designed to accommodate a train approximately 700-feet long. Adequately-wide platforms are provided at all stations; and for safety and convenience, large clearances are maintained between the platform edges and the columns, stairwells, and walls.

Aerial stations have stairways and reversible escalators between the ground floor and platform levels, and subway stations have stairways and reversible escalators between the mezzanine and platform levels. Full-length mezzanines are provided in and between all downtown subway stations, permitting mezzanine distribution of passengers to eliminate street congestion, and providing for the construction of direct-access connections to adjacent buildings. The mezzanine space also can be utilized for concessions, underground store entrances, and for undercrossing the busy surface street.

In all stations attractive architectural treatment is essential with emphasis on appearance, durability, and ease of maintenance. Concrete columns support precast, prestressed concrete roof slabs over the platform of the aerial and surface stations. Structural glazed tile in pleasing hues form the surfaces of the walls of the subway stations. Subway ceilings have acoustical treatment, and fluorescent fixtures illuminate the underground stations. All needed accessories and appurtenances such as telephone booths, benches, concession stands, and information centers are provided.

YARDS AND SHOPS

There are six line yards strategically located throughout the system and one central main yard. Each line yard contains tracks for the storage of cars, facilities for making up trains, and provision for cleaning, inspection, and routine maintenance of the equipment. The main yard provides for these functions and in addition has facilities for major repairs and heavy maintenance.

The layout of storage tracks is arranged for flexible operation. Cars are made up into trains and stored on "ready" tracks prior to dispatching them into the system. A transition zone is provided between these tracks and the main line tracks to change from local yard control to automatic system control. Additional track areas are provided for cleaning and washing, shop access, and storage of returned equipment.

Although the yards may not be completely electrified or fully automatic in operation, full use will be made of the most modern developments in yard operations to provide quick and efficient movement of cars within the yard. To the maximum extent feasible, all yard movements are controlled from a central location within the yard.

In all yards tracks through the shop buildings enable the direct movement of cars to protected servicing and repair areas. Inspection and lubrication pits are provided as well as stock and tool rooms, lockers, offices, lunch, recreation and ready rooms. Heavy maintenance tools, including truck turntables, bridge cranes, truck transfer tables, car lifts, and wheel lathes, are located in the shop building at the main central yard. Facilities are also provided here for painting and for major electrical, brake, and general repair.

The table below lists the distribution of total facilities required at suggested locations with their initial and future storage capacities.

YARDS AND SHOPS

Yard	*Line*	*Design Storage Capacity Number of Cars* 1975	1990
Richmond	Berkeley-Richmond	140	180
Pleasant Hill	Central Contra Costa	90	140
West Oakland*	Trans-Bay	220	280
Union City	Southern Alameda County	145	210
Santa Venetia	Marin	135	190
Lomita Park	Peninsula	200	270
Redwood City	Peninsula	220	280
	Totals	1,150	1,550

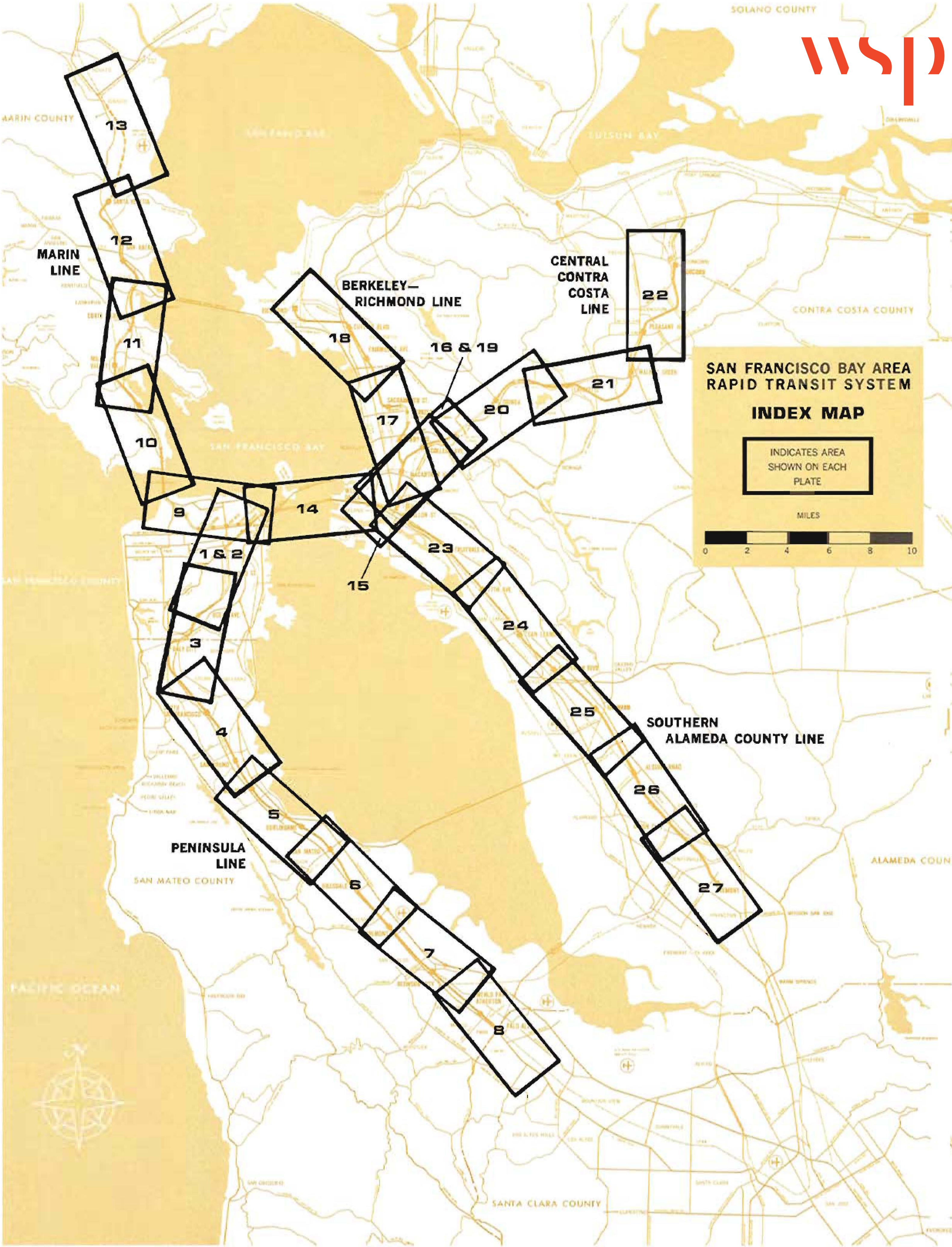
*Central overhaul and repair shop

ADMINISTRATION AND OPERATIONS CENTER

It is proposed that all central administrative and operational functions of the rapid transit system be concentrated in a central administration and operations center. The floor area requirements are based on projected system needs for 1985, which is approximately 15 years after the system is fully open for operation. To develop requirements and the cost estimate for this facility, Mr. Donald C. Hyde, General Manager of the Cleveland Transit System, was consulted in order to benefit from the experience of other rapid transit operations.

Central-office space requirements are included for District directors, general management, and all administrative and operations departments. Also, such miscellaneous support functions as reception, library, cafeteria, stockroom and print shop are included.

THE ROUTES


SAN FRANCISCO BAY AREA RAPID TRANSIT SYSTEM
INDEX MAP
INDICATES AREA SHOWN ON EACH PLATE
MILES
0 2 4 6 8 10
MARIN LINE
BERKELEY—RICHMOND LINE
CENTRAL CONTRA COSTA LINE
SOUTHERN ALAMEDA COUNTY LINE
PENINSULA LINE
SOLANO COUNTY
MARIN COUNTY
SUISUN BAY
CONTRA COSTA COUNTY
SAN FRANCISCO BAY
SAN FRANCISCO COUNTY
SAN MATEO COUNTY
ALAMEDA COUNTY
SANTA CLARA COUNTY
PACIFIC OCEAN
1 & 2
3
4
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6
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GENERAL

The pattern of development in the San Francisco Bay Area is influenced largely by topography. The principal centers are well established, and the main travel corridors are well defined. The proposed system of rapid transit is oriented to serve these centers of development and to follow these established travel corridors.

The system includes stations serving the downtown areas of San Francisco and Oakland, which have dense business populations and connecting lines and stations serving the interrelated communities of the Bay Area. West Bay and East Bay are connected by the Trans-Bay Line with five rapid transit lines radiating from this central-core area.

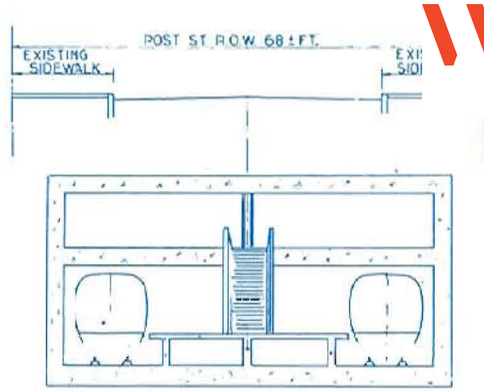
From downtown San Francisco, the Marin Line extends to the Golden Gate Bridge and then into Marin County. The Peninsula Line proceeds through San Mateo County to Palo Alto, just within Santa Clara County. From downtown Oakland, the Berkeley-Richmond Line proceeds through Berkeley and into Contra Costa County. The Central Contra Costa Line pierces the Berkeley Hills to the east and serves central Contra Costa County. The Southern Alameda County Line extends south serving the south East Bay.

The following pages describe the proposed rapid transit routes. Illustrating each line are plans and profiles at a scale of one inch equals 4,000 feet. These plans are based upon detailed photo-mosaic engineering plans at a scale of one inch equals 200 feet.

For estimating purposes, the system is divided into eight major segments: San Francisco Downtown, Peninsula Line, Marin Line, Trans-Bay Line, Oakland Downtown, Berkeley-Richmond Line, Central Contra Costa Line, and Southern Alameda County Line.

The descriptions in the following pages specify the boundaries of each segment. The cost to construct each segment is given in the section on Estimates.

In all, there are about 120 miles of two-track rapid transit line and 52 stations. Underground construction is proposed for 24 miles; overhead construction for 44 miles; and surface construction for 52 miles.



SECTION

SAN FRANCISCO DOWNTOWN

The San Francisco Downtown element of the Bay Area regional rapid transit system consists of a four-track, two-level subway beneath Market Street and a two-track, single-level subway beneath Post Street.

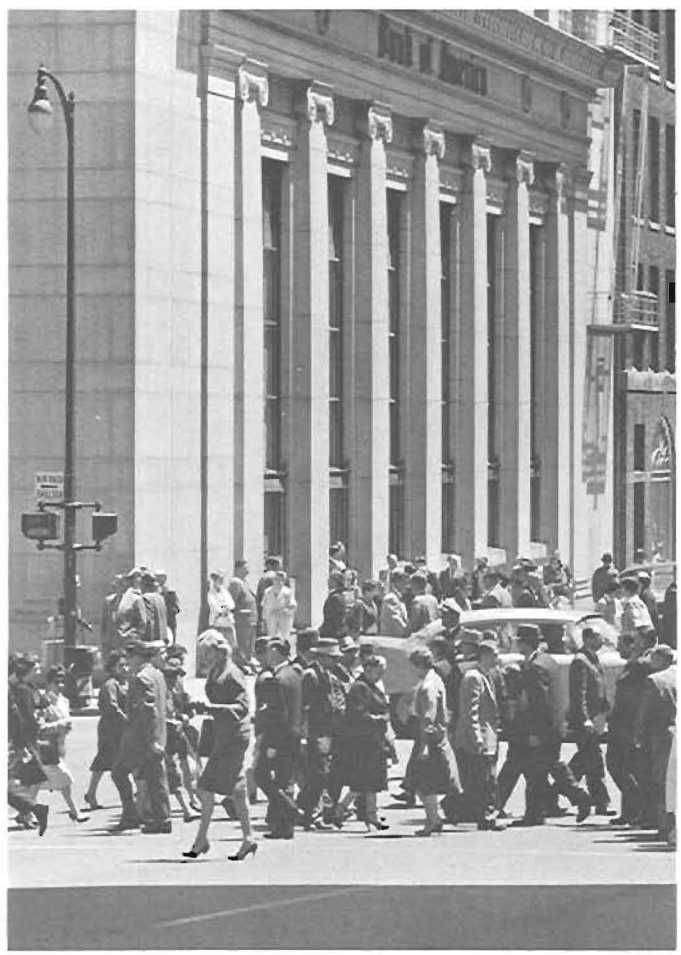
The Marin Line connection in Post Street begins at the Kearny Street Station, a terminal subway station, adjoining the Montgomery Street Station in Market Street and permitting passenger transfer. The Union Square Station at Powell Street serves the shopping area and a continuous underground mezzanine is planned between these two downtown delivery stations, affording convenient access and distribution along Post Street. The line continues in underground construction to the Van Ness Avenue Station and to a point near Laguna Street where the San Francisco Downtown segment ends and the Marin Line proper begins.

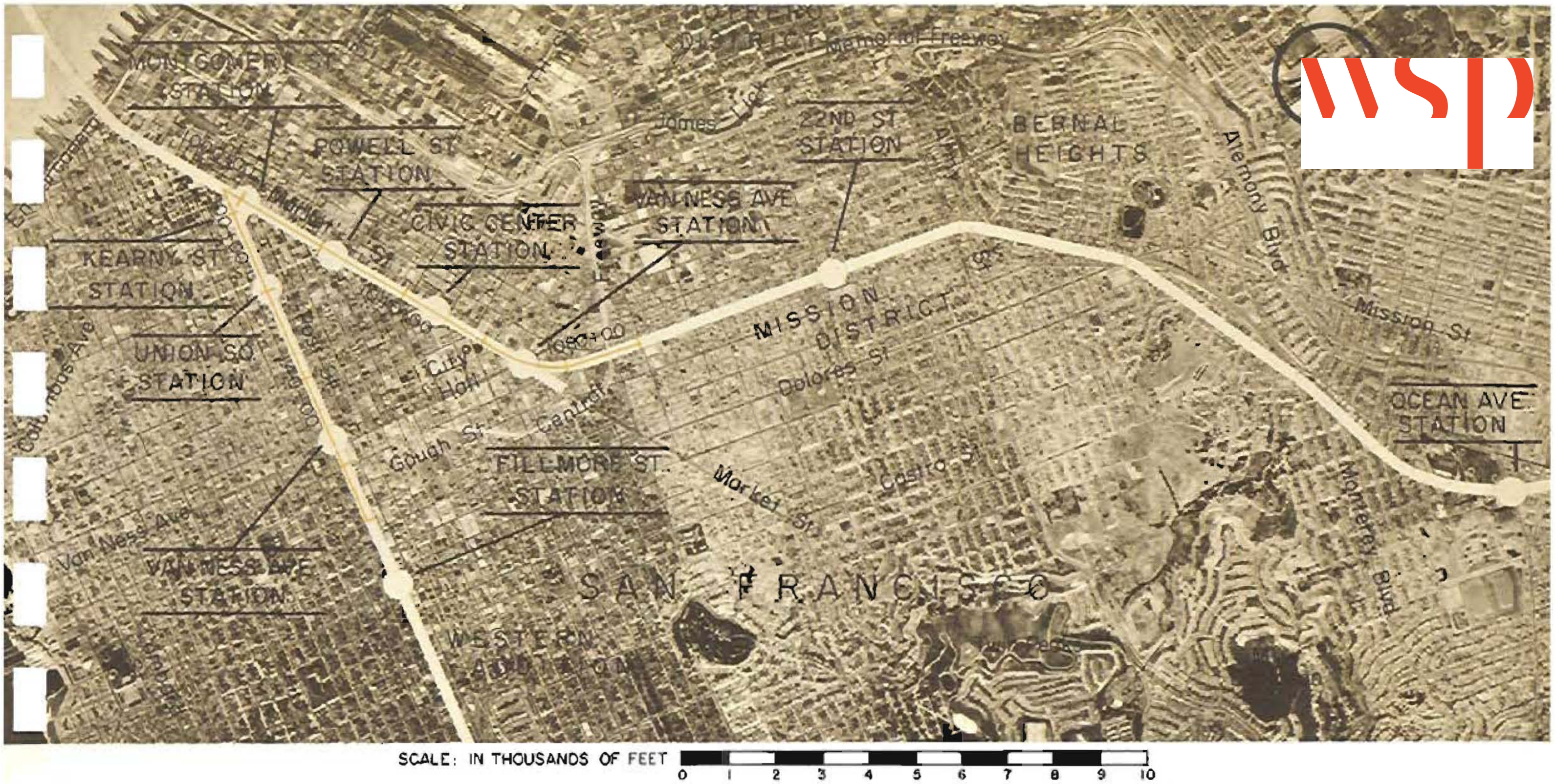
At Montgomery Street, the Market Street subway joins the San Francisco approach to the Trans-Bay Tube. The subway extends up Market Street to about Van Ness Avenue where it swings to the south to become the Peninsula Line in Mission Street. The lower level of the subway provides through regional service by joining the Peninsula and the Trans-Bay Lines. The upper level is built to accommodate local rapid transit trains at a future time and will be utilized initially by the streetcars of the San Francisco Municipal Railway. Streetcars on the five routes which converge on Market Street enter the subway upper level at Gough Street, and operate beneath Market Street to Sansome Street, where they return to surface operation.

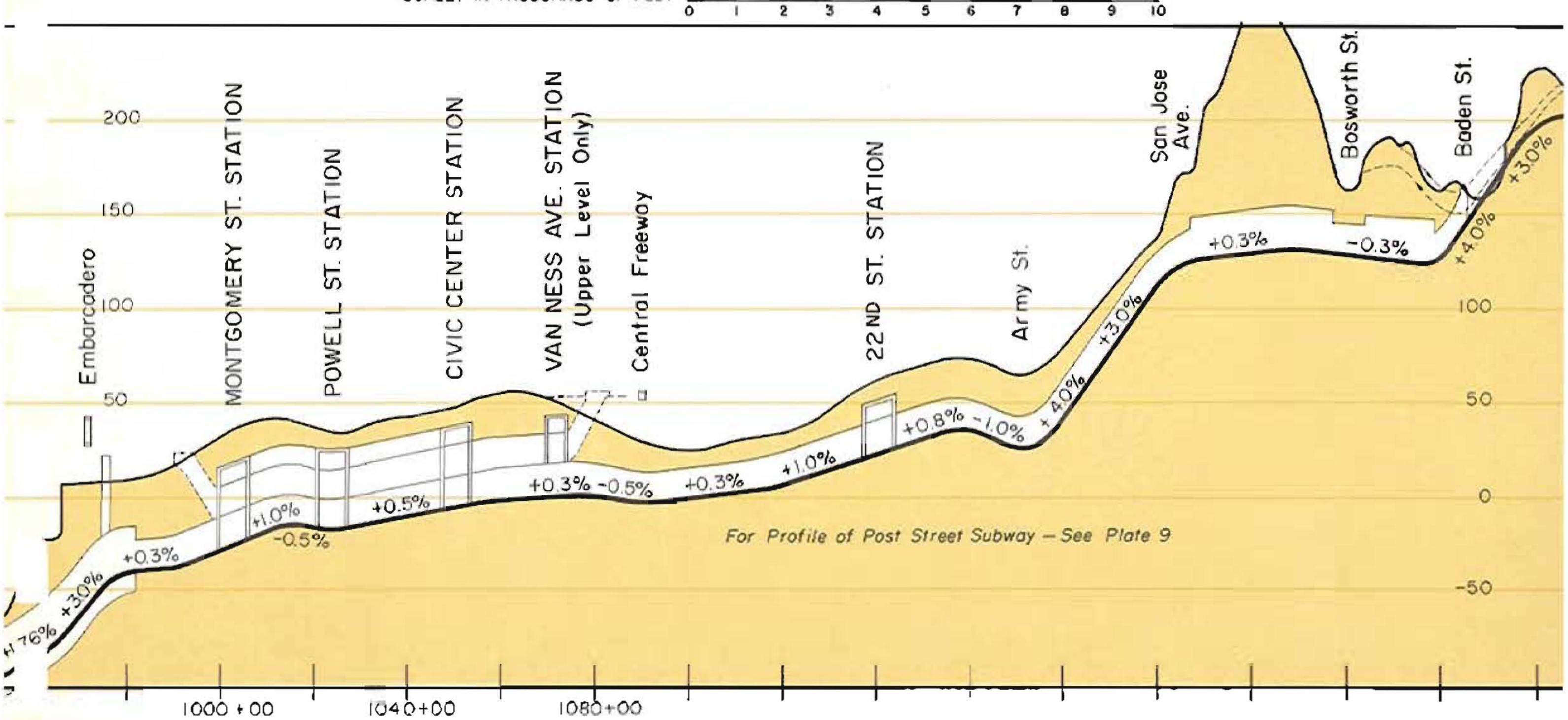
Both levels of the Market Street subway are served by three stations in Market Street. The Montgomery Street Station serves the financial district, the Powell Street Station serves the commercial and shopping area, and the Civic Center Station serves the Civic Center and vicinity. These stations have full mezzanines and are connected by a continuous mezzanine, providing effective distribution of patrons entering or leaving the system. Connections to the street level and to stores and buildings are placed at intervals along Market Street.

A fourth station to serve the upper-level subway only is proposed at Van Ness Avenue. In this area the lower-level subway leaves Market Street to assume an alignment in subway beneath Otis Street, thence into Mission Street. The two-track subway proceeds along Mission Street and at 14th Street joins the Peninsula Line.

The Market Street subway and the connection to Mission Street and the Peninsula Line is 1.9 miles long and includes four stations. The Marin Line connection in Post Street is 1.4 miles long and includes three stations.

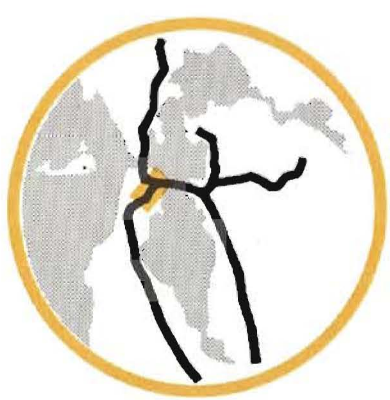






SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

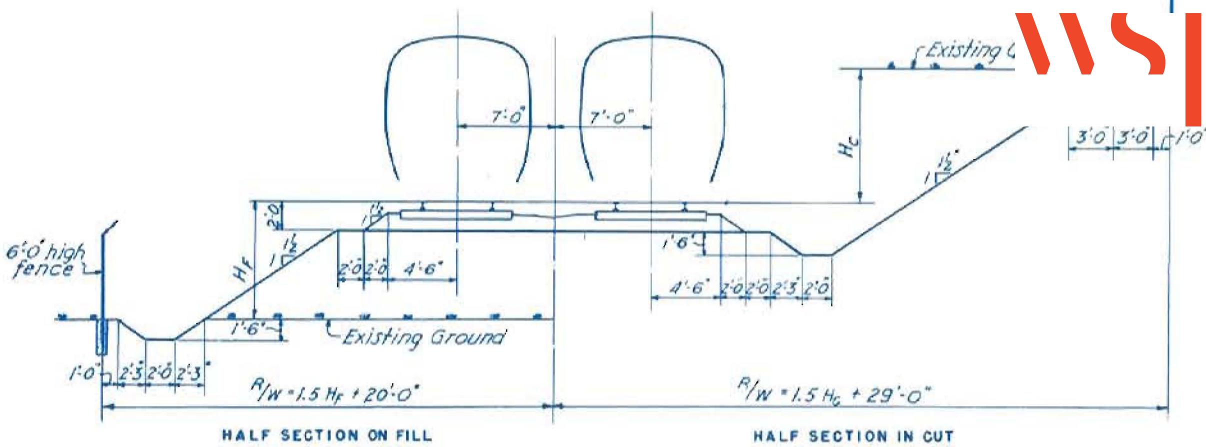
PLATE 1



SAN FRANCISCO
DOWNTOWN

INDICATES AREA SHOWN BY THIS PLATE

PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS



PENINSULA LINE

The Peninsula Line leaves San Francisco Downtown via Mission Street, beginning at 14th Street. The two-track, single-level subway proceeds down Mission Street to a station at 22nd Street in the Mission District. This subway station has a full-length mezzanine.

Near 30th Street the subway leaves Mission Street and swings westward through a tunnel under Bernal Heights. Provision is made for a future subway station beneath Bosworth Street. Continuing underground the line crosses under Monterey Boulevard and enters the alignment of the Southern Freeway.

At the Baden Street overcrossing the tracks come to the surface in the median of the freeway, and at Ocean Avenue a center-platform station is planned. At Sickles Street the tracks leave the freeway median in tunnel beneath the eastbound Southern Freeway lanes, Alemany Boulevard, and San Jose Avenue. An on-grade section between the freeway and DeLong Street carries the line into Daly City.

In Daly City the line rises on aerial structure along the east side of the Southern Pacific San Bruno Branch line to the Daly City Station just north of Knowles Avenue. The line leaves the railroad alignment in Colma, swinging onto the abandoned right of way of the Market Street Railway in the center of El Camino Real.

Entering South San Francisco the alignment is west of the Southern Pacific branch line, and the transit line descends to grade, approaching the South San Francisco Station north of Chestnut Avenue. The line south of the station is on aerial structure to cross Chestnut, Orange, and Spruce Avenues, and it descends to grade just north of Forest Lane in San Bruno.

From this point to its terminus in Palo Alto, the Peninsula Line is generally at grade and on the west side of the Southern Pacific main line tracks. Grade crossings are eliminated by grade-separation structures carrying traffic over or under the rapid transit tracks and the Southern Pacific tracks.

The San Bruno Station is just south of Angus Avenue where there is a connection to the Lomita Park Yard on the east side of the Southern Pacific Railroad.

The Millbrae Station is located at Center Street. A grade-separation overcrossing carries an extension of Millwood Drive over the tracks to tie in with the existing Airport Interchange on the Bayshore Freeway.

At Burlingame, grade-separation structures carry Broadway and Oak Grove Avenue over the tracks. Just south of the Burlingame Station, the Market Street Railway right of way ends, and south of this point the Peninsula Line parallels the Southern Pacific main line tracks. Overcrossings are provided at Howard Avenue and Peninsular Avenue.

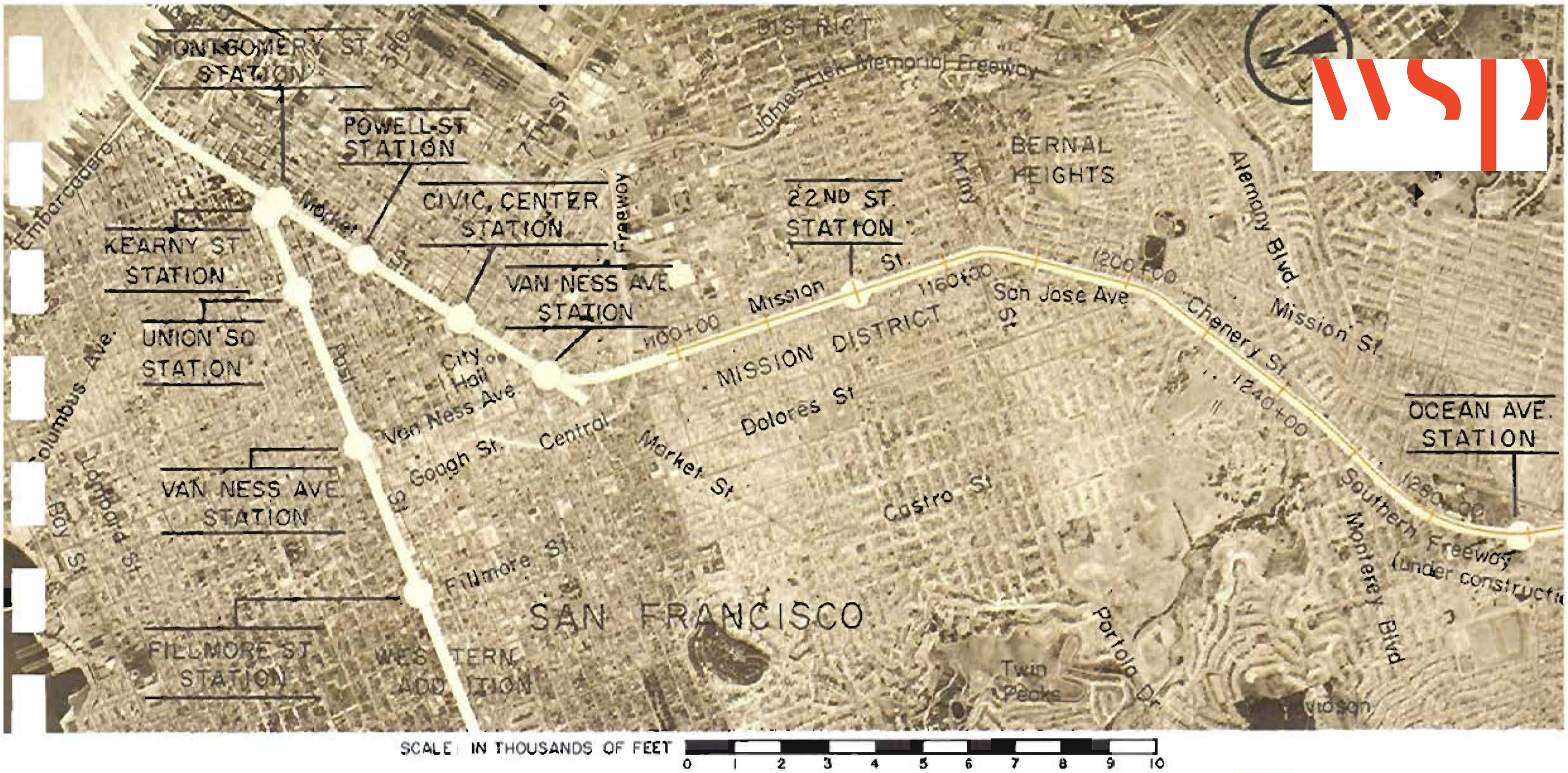
At 3rd and 5th Avenues in downtown San Mateo, one-way undercrossings are planned, and the San Mateo Station is located just south of 5th Avenue.

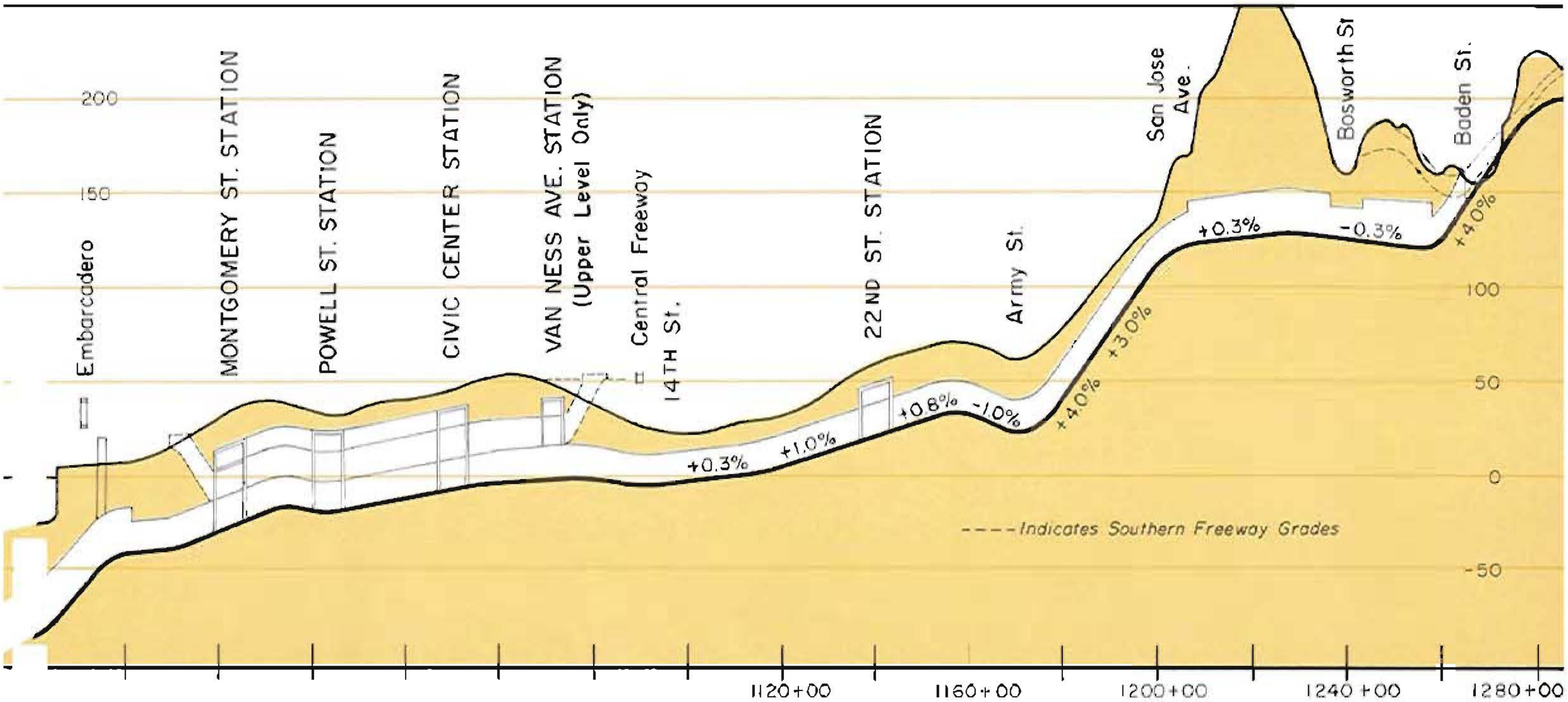
The line continues on the west side of the Southern Pacific tracks to the Hillsdale Station at 25th Avenue. Just north of the station and 25th Avenue, the Saratoga Drive undercrossing extends that street from South Delaware Street to El Camino Real, and at Hillsdale Boulevard an undercrossing provides separation of that boulevard and El Camino Real. The Carlmont Station is opposite Hull Drive between Harbor Boulevard and Holly Street. Ralston Avenue is carried over the tracks and El Camino Real on a grade-separation structure. In San Carlos, Holly Street and Brittan Avenues cross over the tracks and El Camino Real.

In Redwood City, Hopkins and Jefferson Avenues cross under the Peninsula Line, and overcrossings are provided for Brewster Avenue and Main Street. The Redwood City Station is between Jefferson Avenue and Main Street. The Redwood Yard is located just north of Semicircular Road. A station, Menlo Park-Atherton Station, is located just north of Ravenswood Avenue.

At the San Mateo-Santa Clara County Line, the state plans the Willow Road Expressway crossing over the on-grade tracks. The Peninsula Line terminus is just within Santa Clara County at the Palo Alto Station near the Stanford Shopping Center.

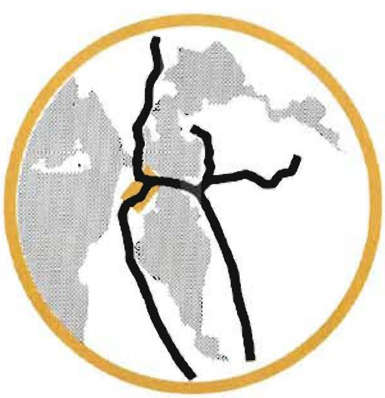
The Peninsula Line is 31.1 miles long and includes thirteen stations.





SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 2



PENINSULA LINE

STATION 1097+00 TO STATION 1240+00

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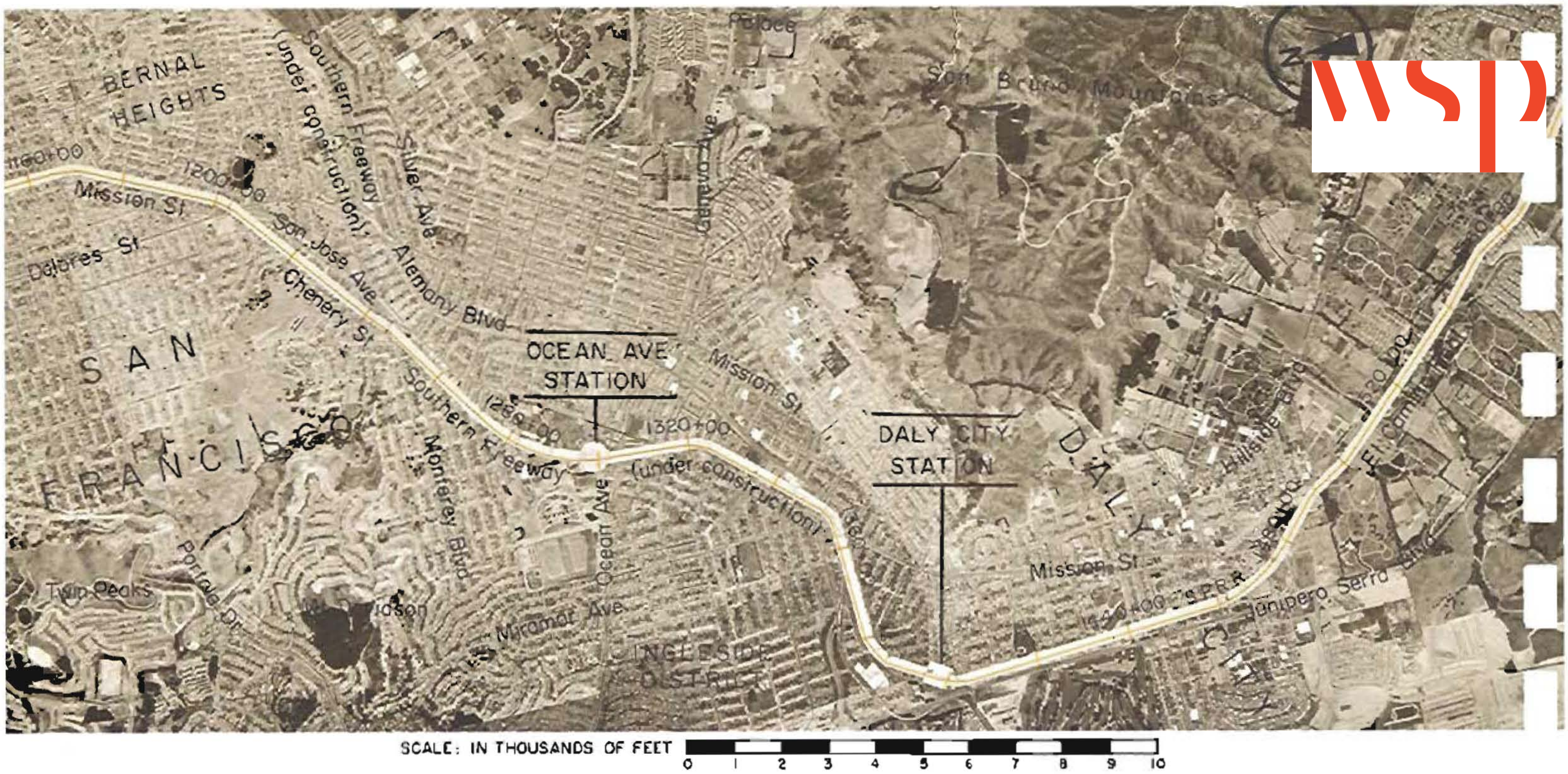
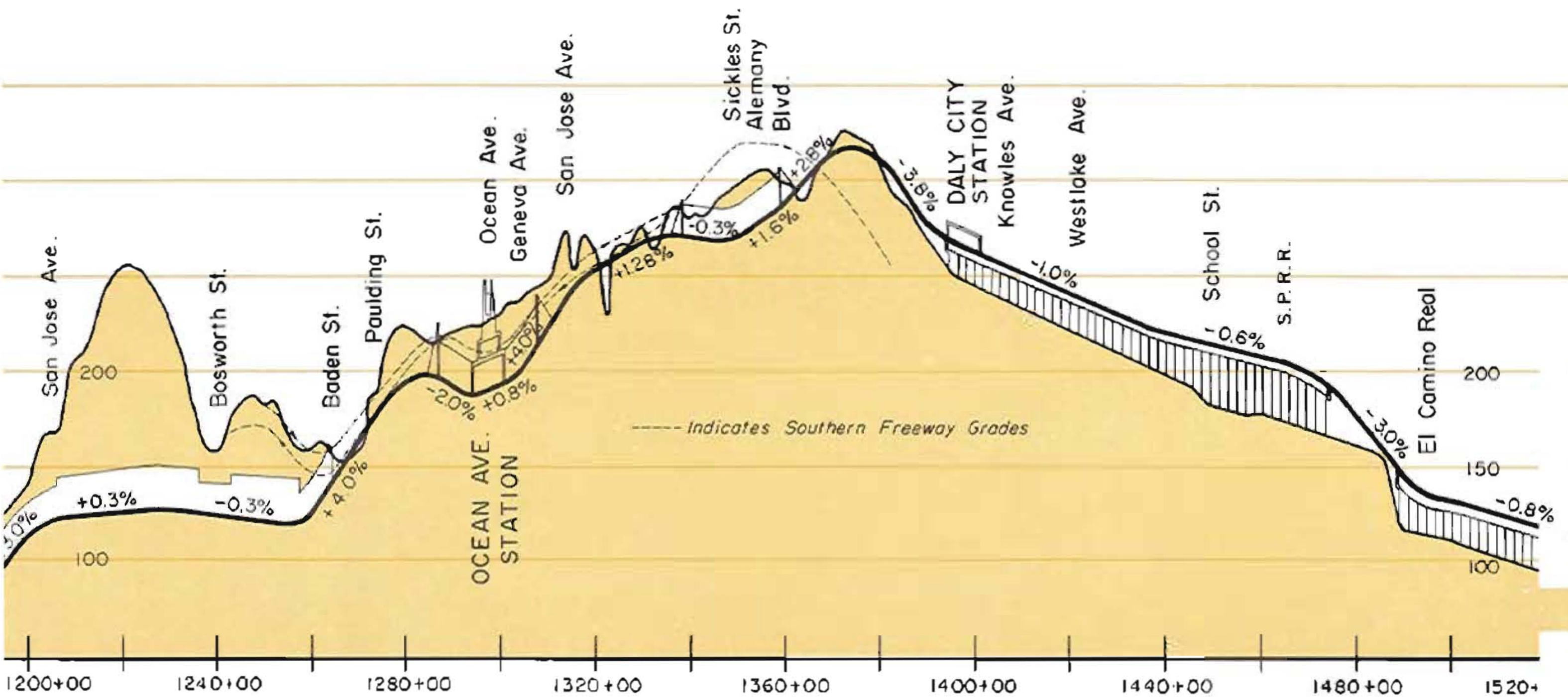
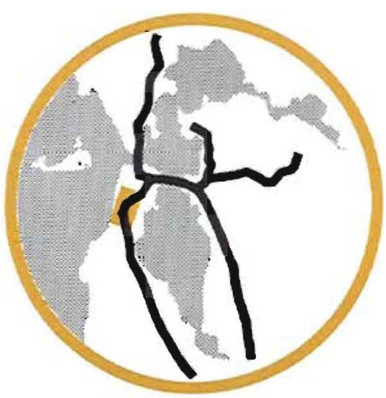
PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS





SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 3

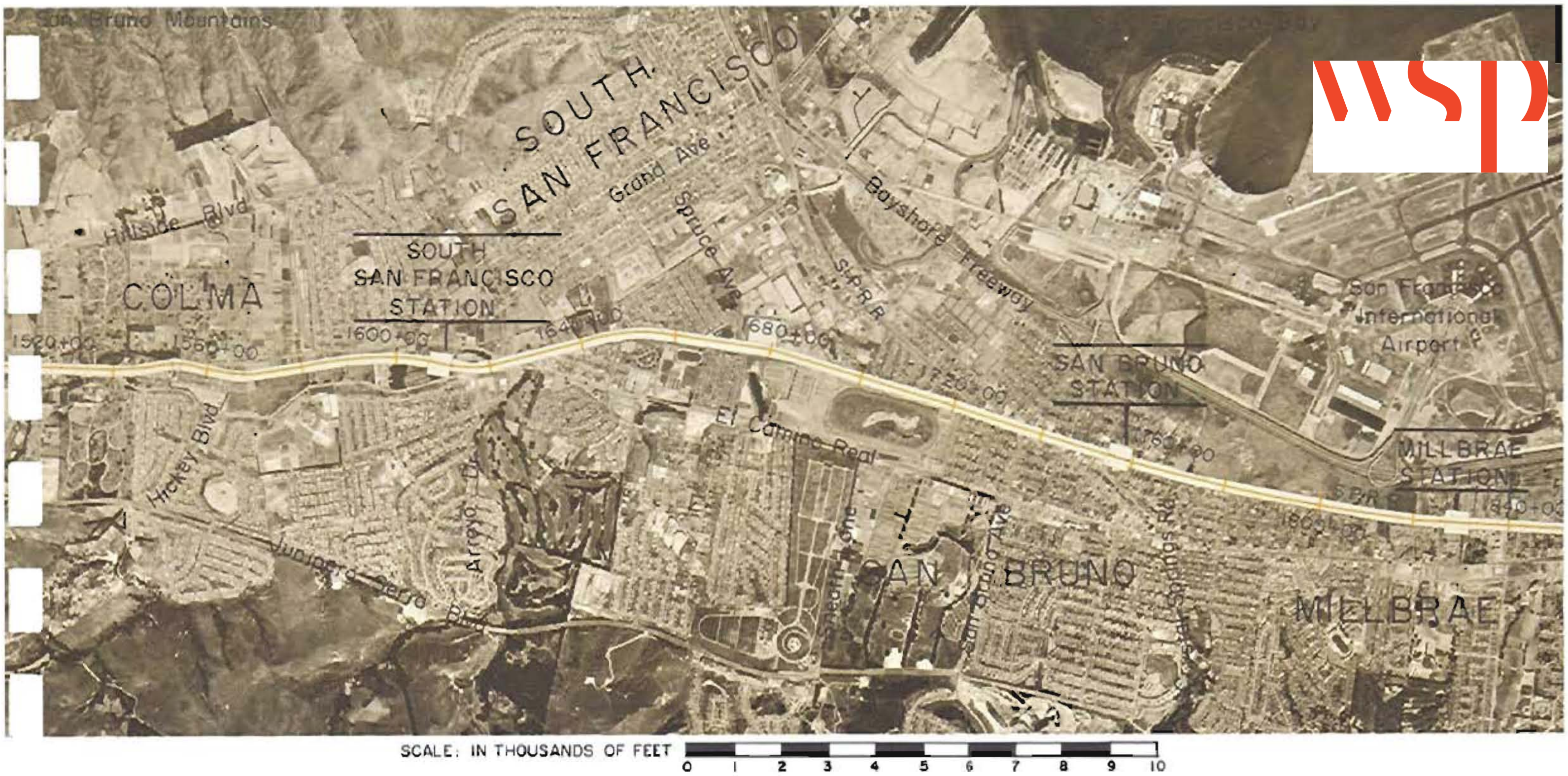


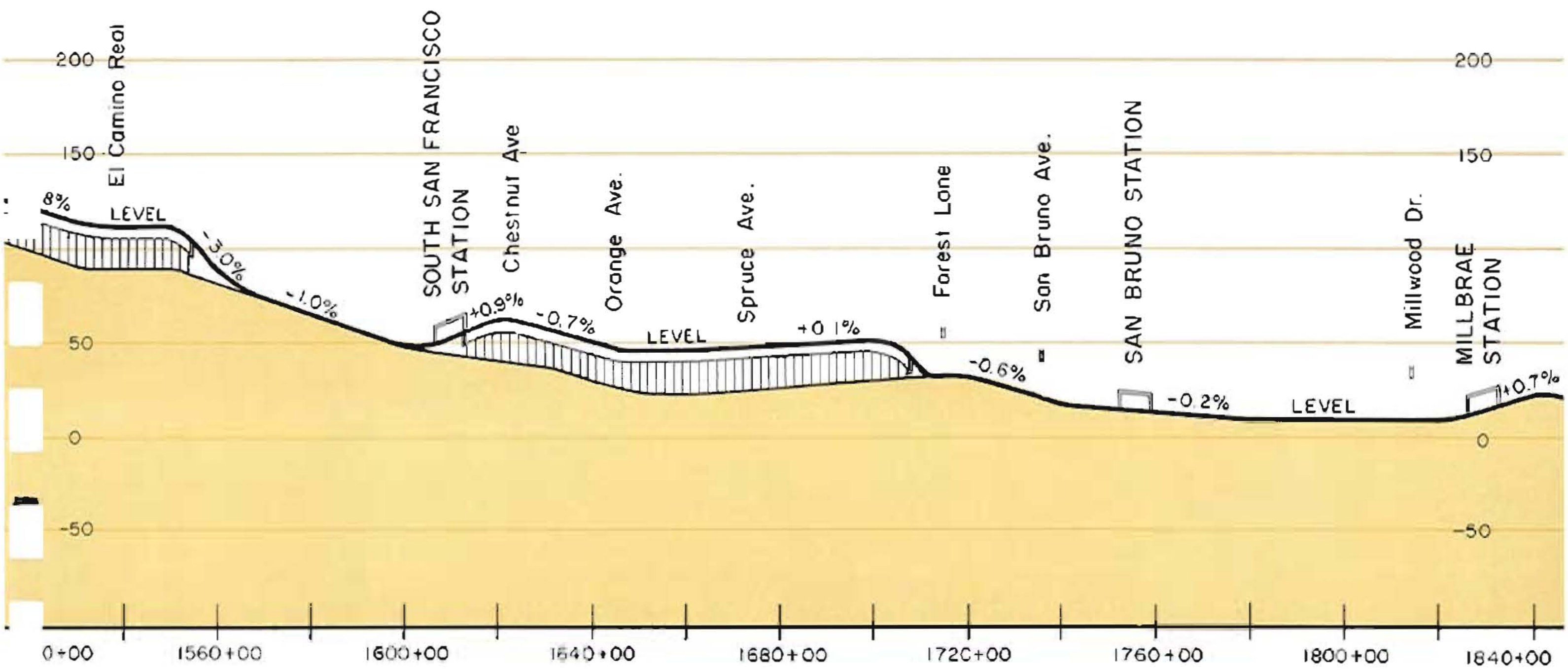
PENINSULA LINE

STATION 1240+00 TO STATION 1520+00

INDICATES AREA SHOWN BY THIS PLATE

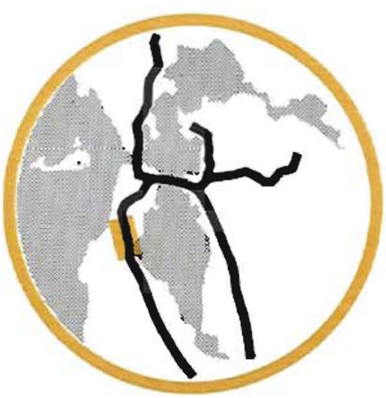
PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS





SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 4

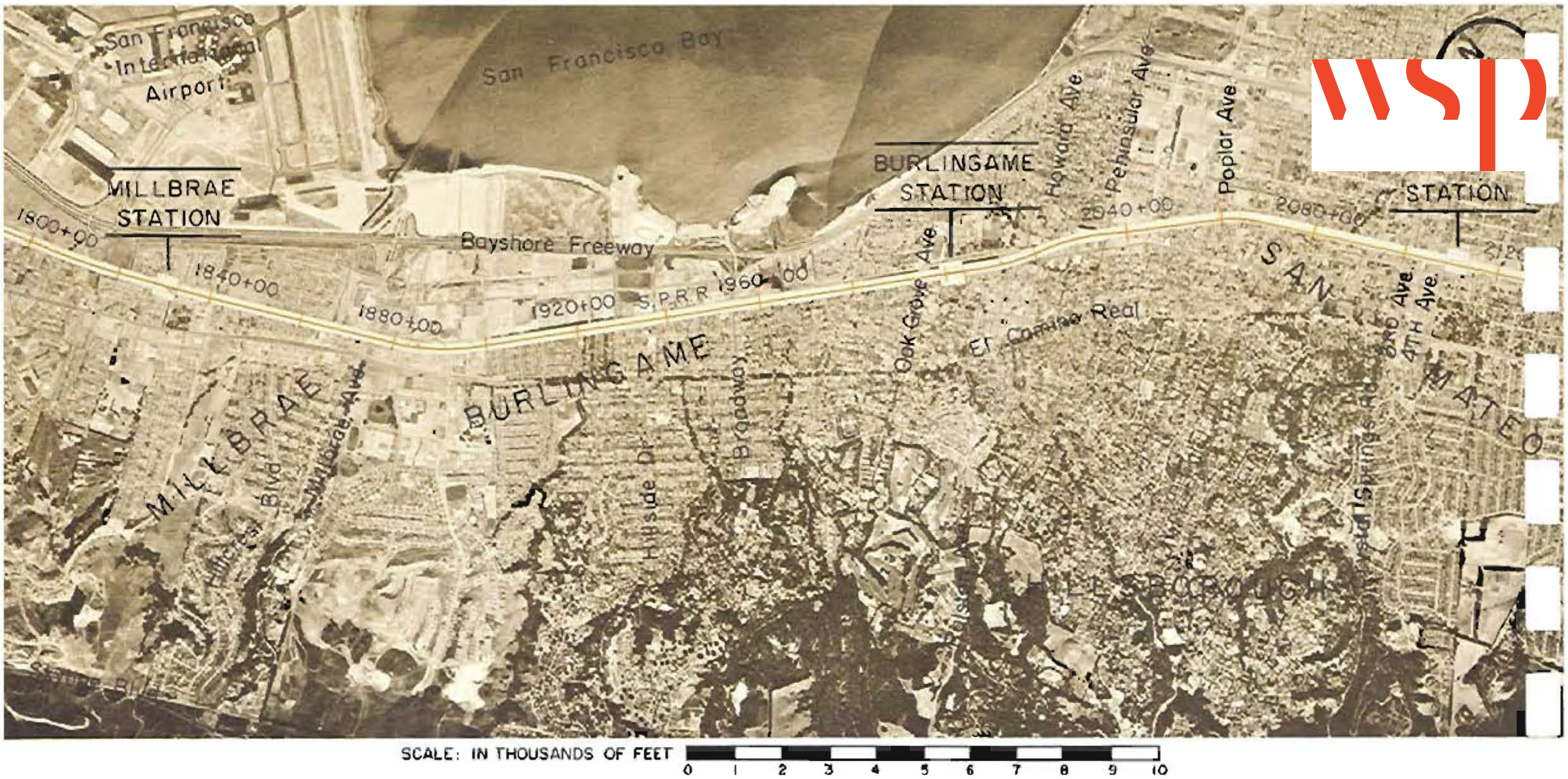


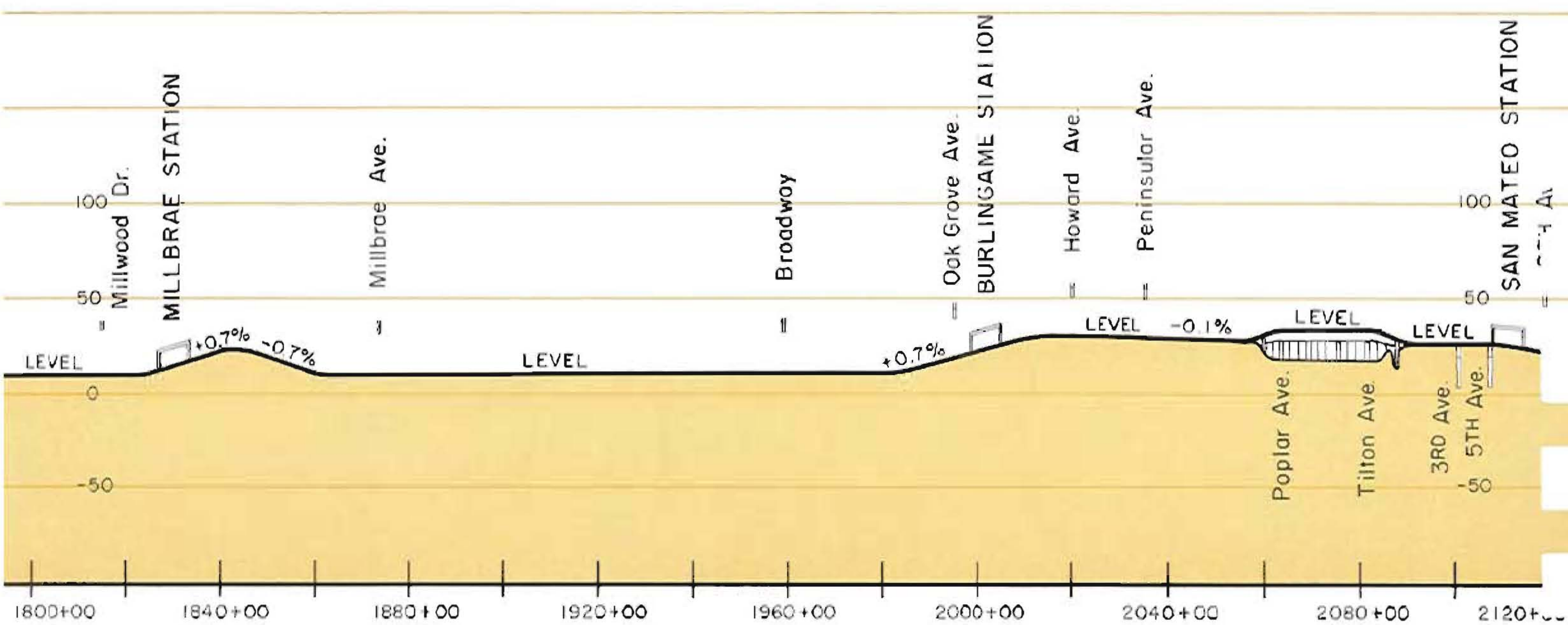
PENINSULA LINE

STATION 1520+00 TO STATION 1800+00

INDICATES AREA SHOWN BY THIS PLATE

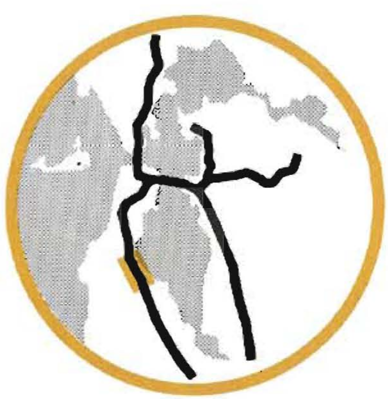
PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS





SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 5

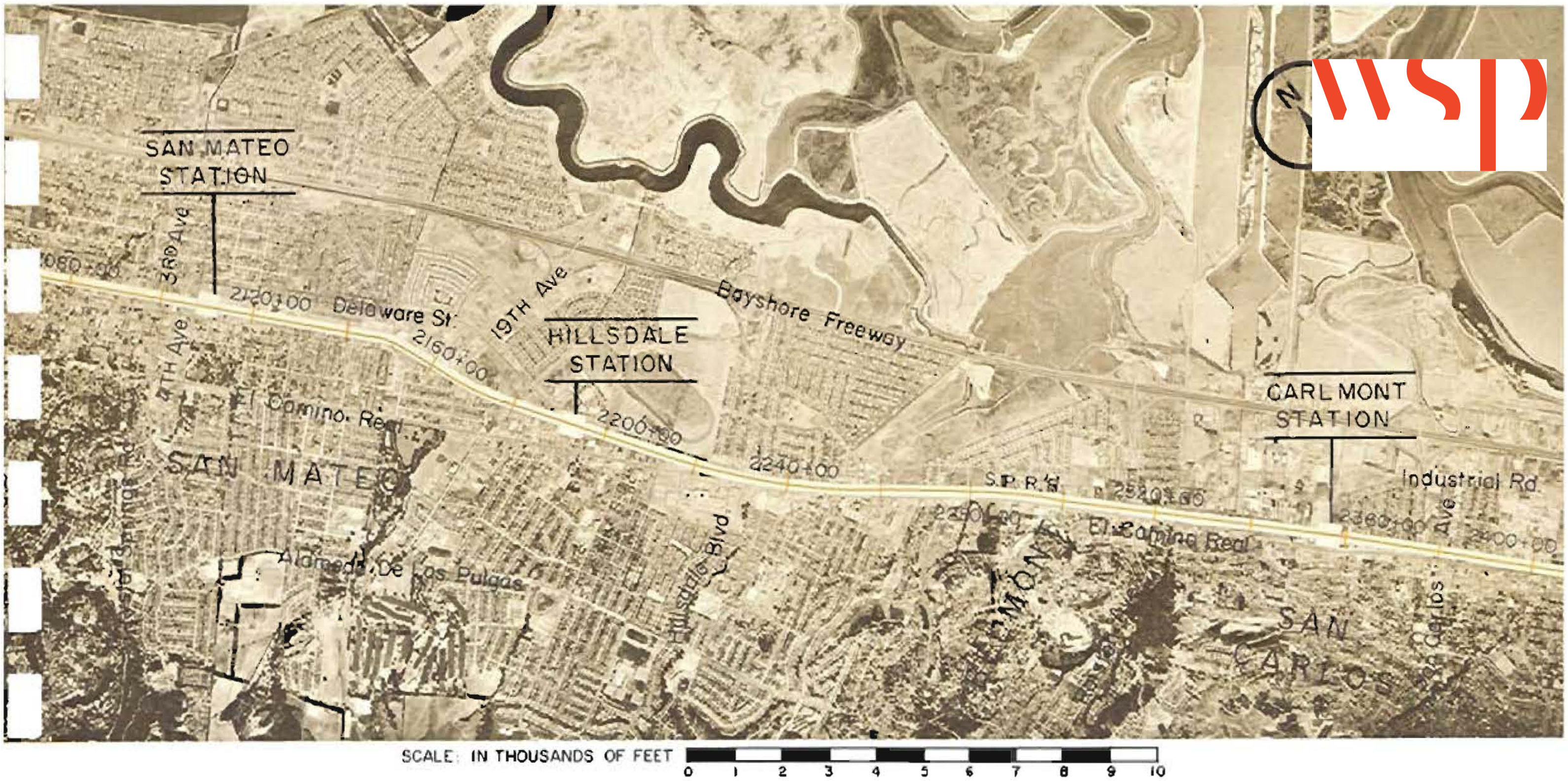


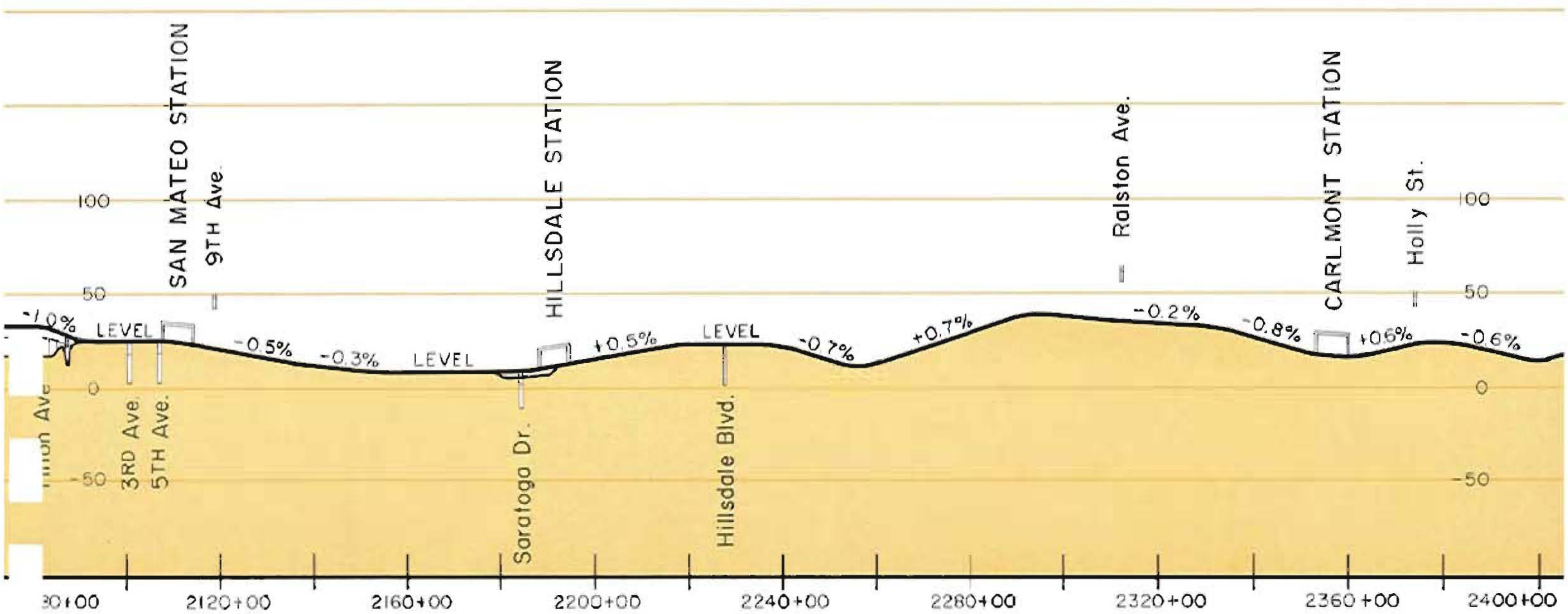
PENINSULA LINE

STATION 1800+00 TO STATION 2080+00

INDICATES AREA SHOWN BY THIS PLATE

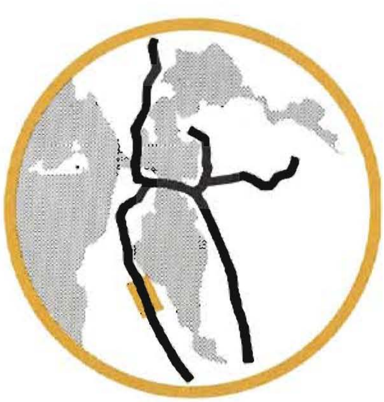
PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS





SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 6



PENINSULA LINE

STATION 2080+00 TO STATION 2360+00

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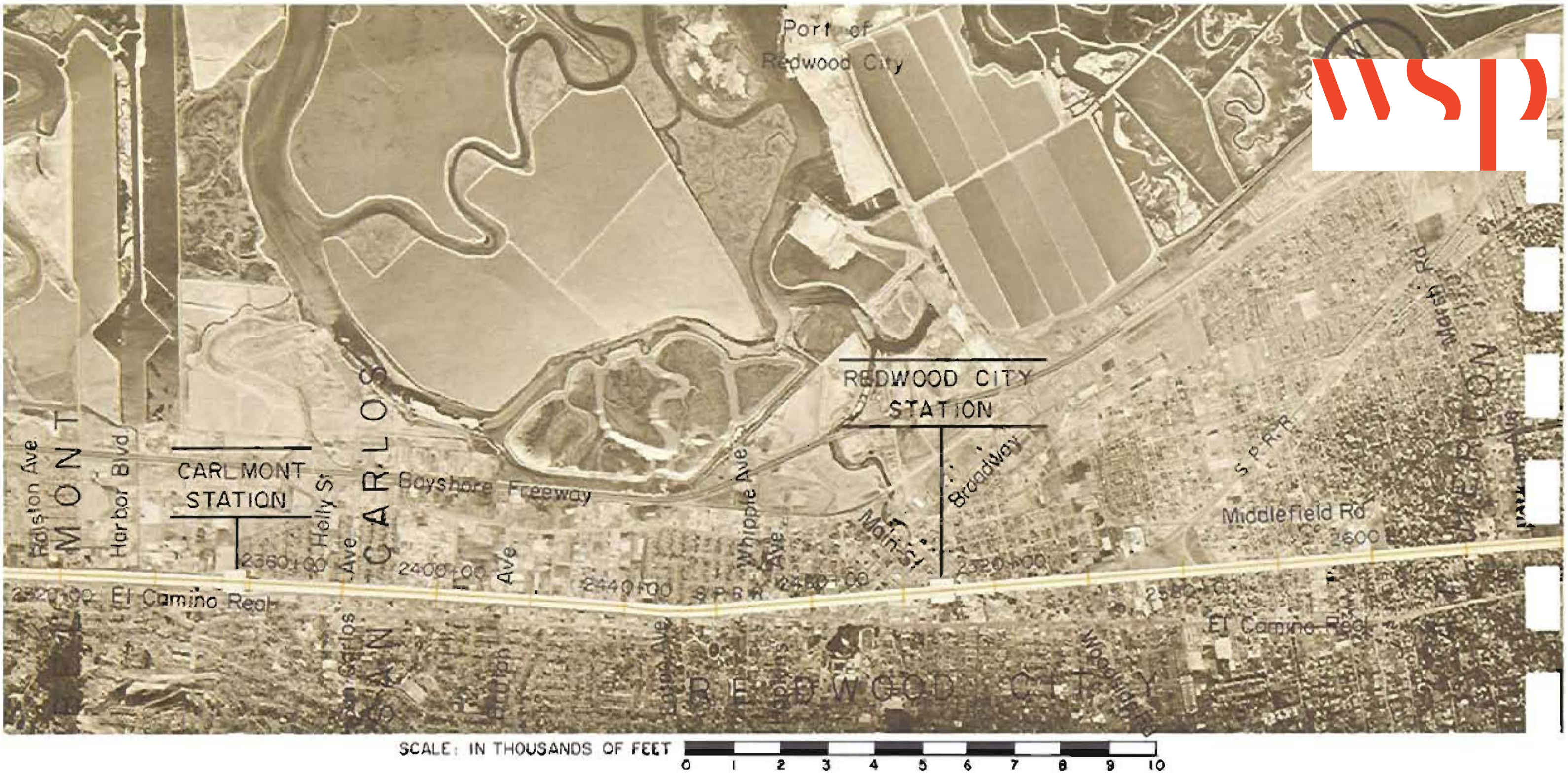
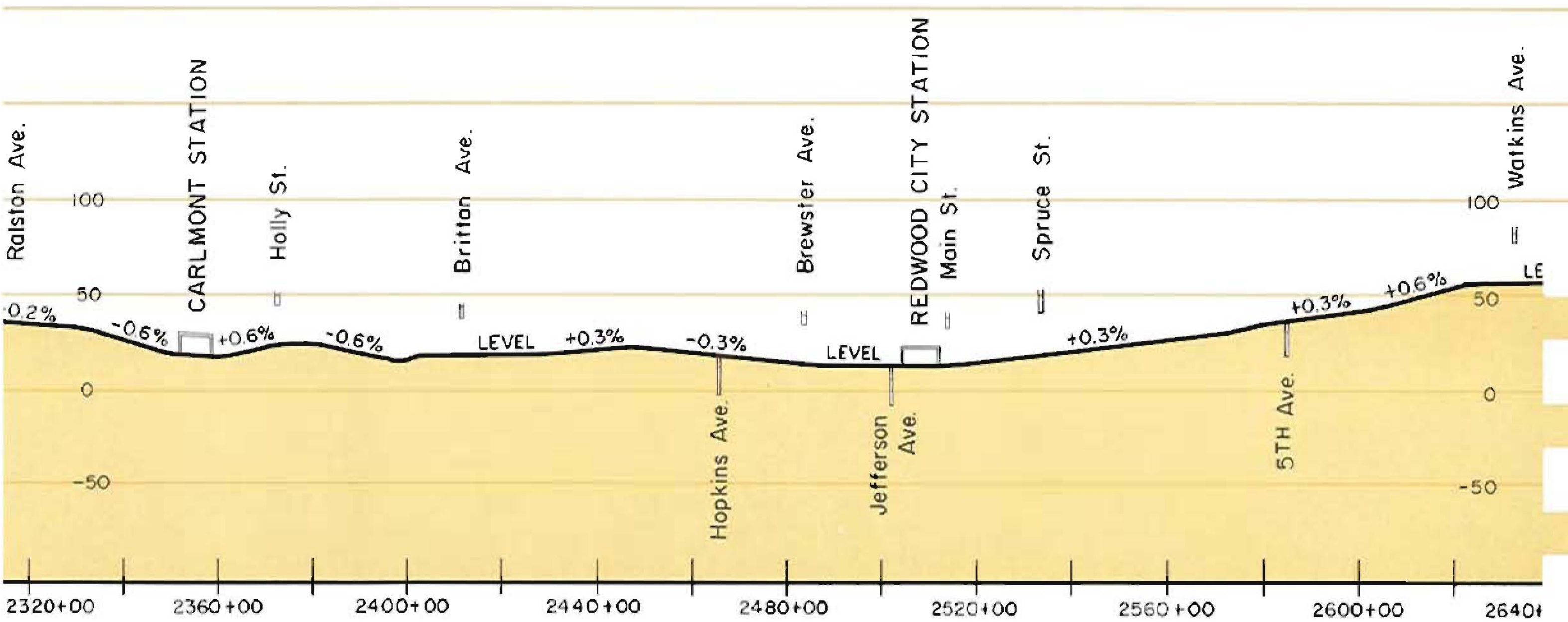
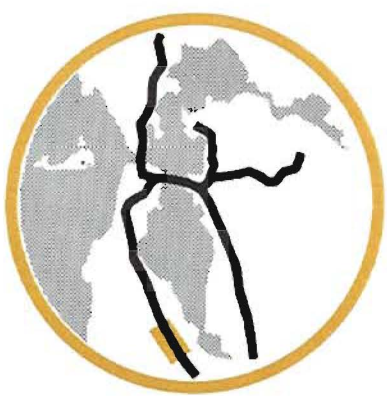
PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS





SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 7

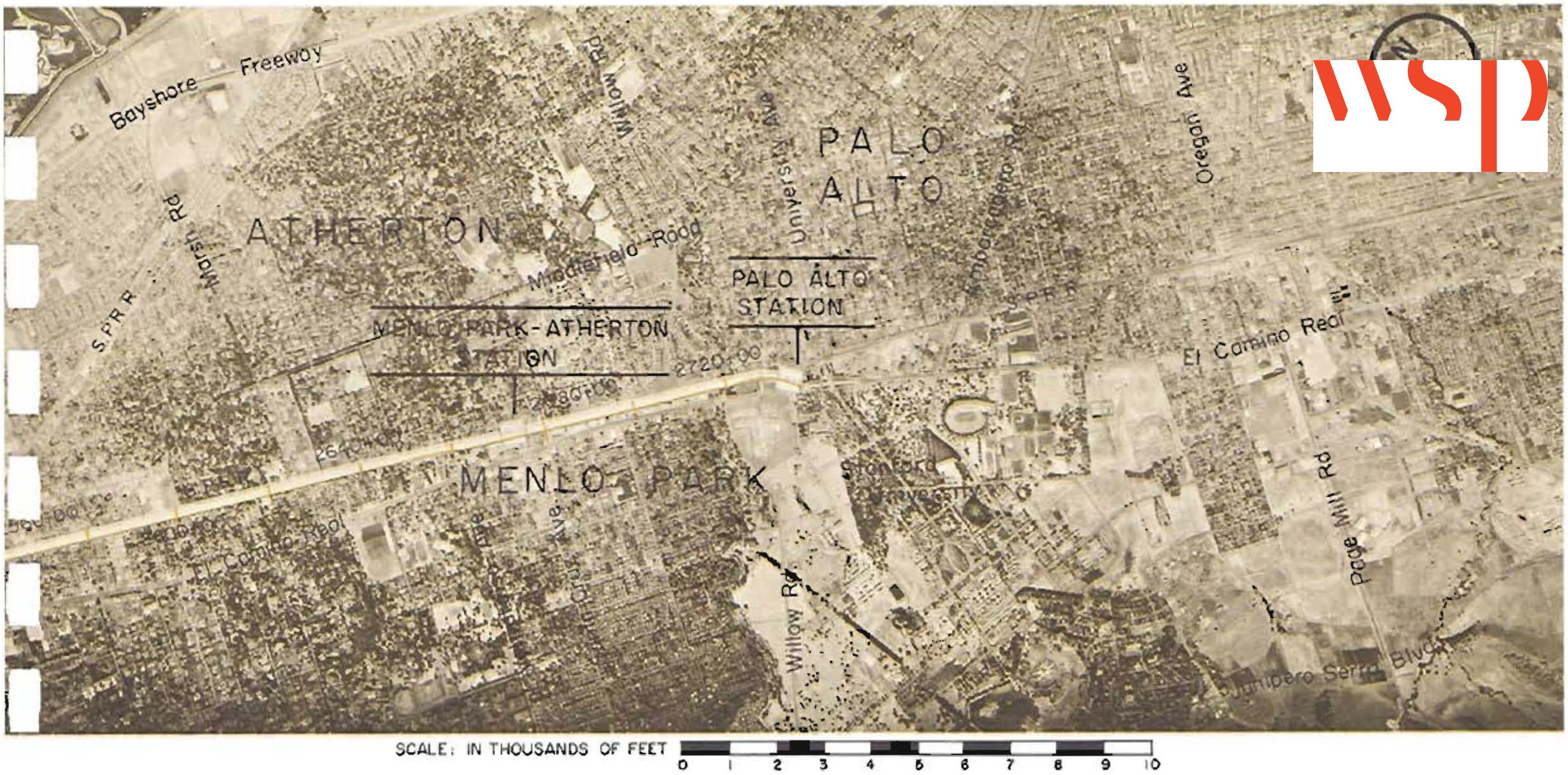


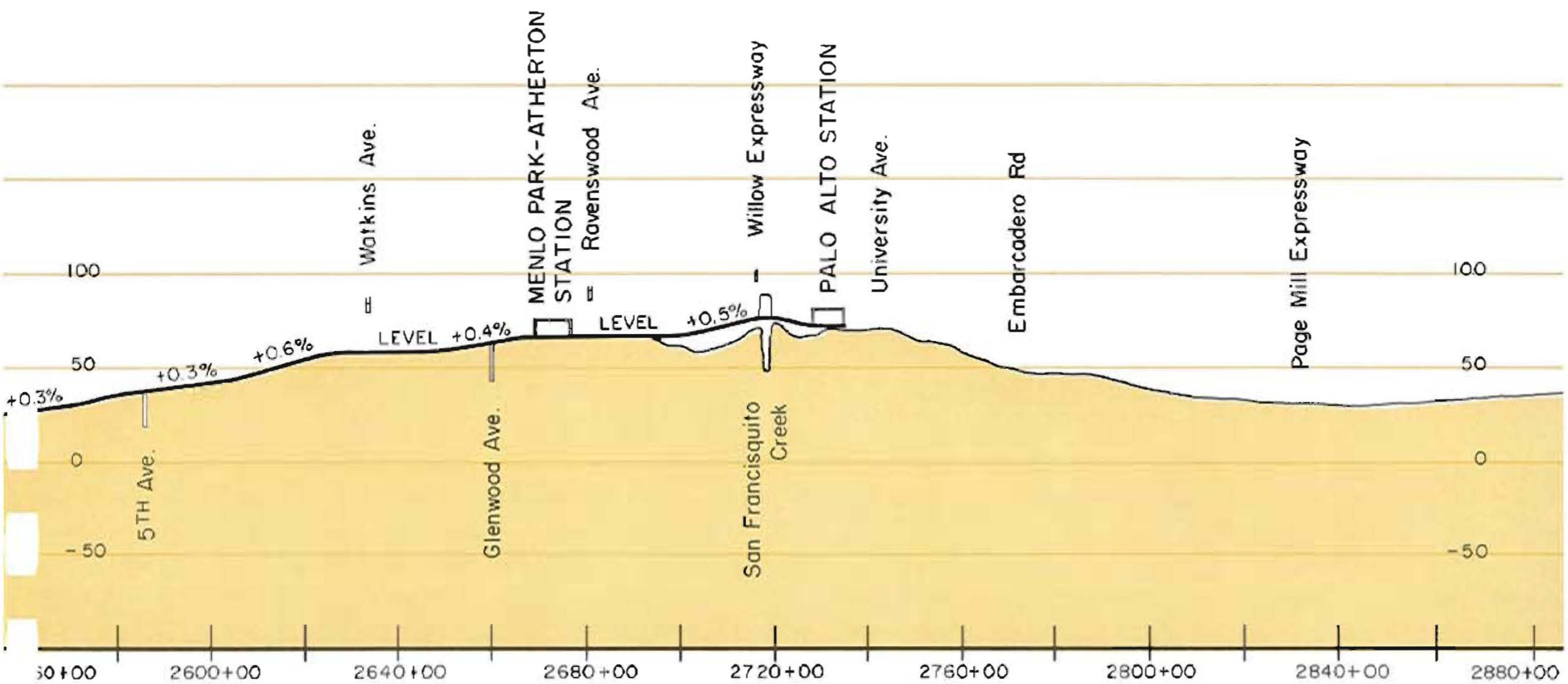
PENINSULA LINE

STATION 2360+00 TO STATION 2600+00

INDICATES AREA SHOWN BY THIS PLATE

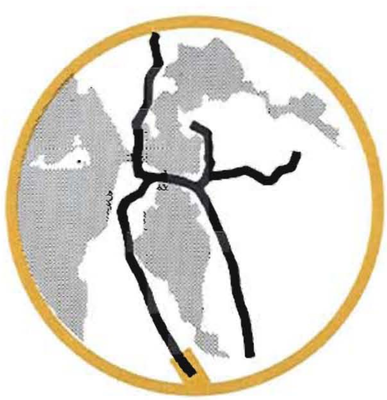
PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS





SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 8

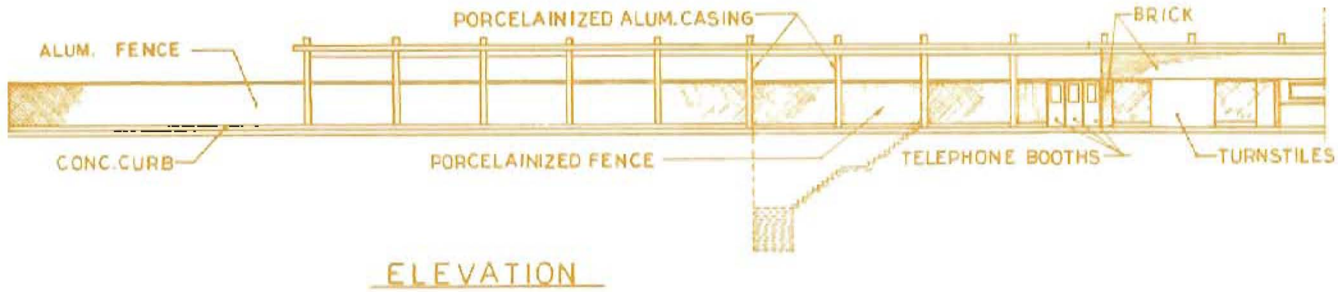


PENINSULA LINE

STATION 2600+00 TO STATION 2735+00

INDICATES AREA SHOWN BY THIS PLATE

PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS



MARIN LINE

The connection to the Marin Line leaves San Francisco Downtown in subway under Post Street at a point between Octavia and Laguna Streets. At this point the San Francisco Downtown segment ends and the Marin Line begins.

The line proceeds in subway under Post Street to the Fillmore Street Station, serving the Western Addition. The Presidio Avenue Station is located in deep subway, and just west of this station the line curves northward to a tunnel under Pacific Heights, emerging in the Presidio near the foot of Maple Street.

After a short section of on-grade construction, the Marin Line goes underground to tunnel deep beneath Arguello Boulevard. At the Golden Gate Bridge Freeway (Funston Avenue approach) the line is in subway. Curving northward, again in tunnel, it passes under Fort Winfield Scott and Lincoln Boulevard and approaches the Golden Gate Bridge.

The two rapid transit tracks are carried into the truss spans and arch span of the south approach structure and proceed across the Golden Gate Bridge at the elevation of the lower chord of the stiffening truss of the suspension bridge.

Leaving the alignment of the Golden Gate Bridge, the Marin Line enters a tunnel beneath Vista Point and emerges above Fort Baker. The line crosses above a portion of Fort Baker to enter the Sausalito Tunnel, which is 1.7 miles in length and one of the major structures in the system. The line crosses beneath Bridgeway Boulevard and ascends to the Sausalito Station on aerial structure.

The line continues within the Northwestern Pacific Railroad right of way and, at the foot of Waldo Grade, descends to on-grade construction under Richardson Bay Bridge. It then crosses the marshlands to the Mill Valley Station at East Blithedale Avenue. North of Mill Valley at the line leaves the railroad right of way and curves eastward to enter a one-half mile tunnel. From the tunnel portal south of the Corte Madera Interchange, the line emerges to cross above the Route 101 Freeway and to follow along the west side of the Northwestern Pacific Railroad on grade to the Corte Madera Station at Tamalpais Drive.

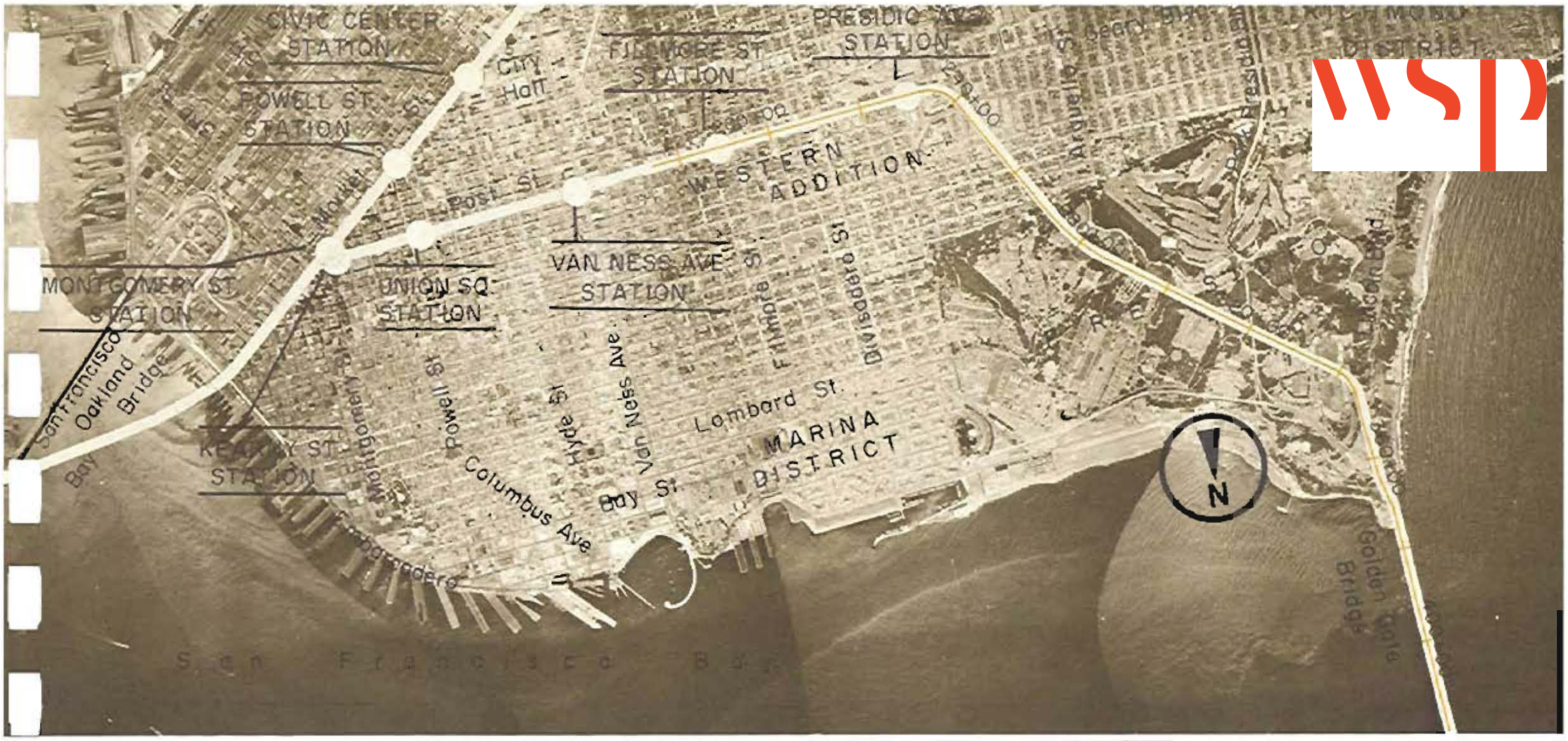
North of the Corte Madera Station, the Marin Line rises on aerial structure and crosses for the first time to the east side of the Northwestern Pacific Railroad. The aerial structure is continued across Corte Madera Creek and Sir Francis Drake Boulevard East. North of these crossings, the line continues parallel to the railroad in a tunnel and then proceeds on structure beneath the California Park Overhead and into the industrial sector of San Rafael.

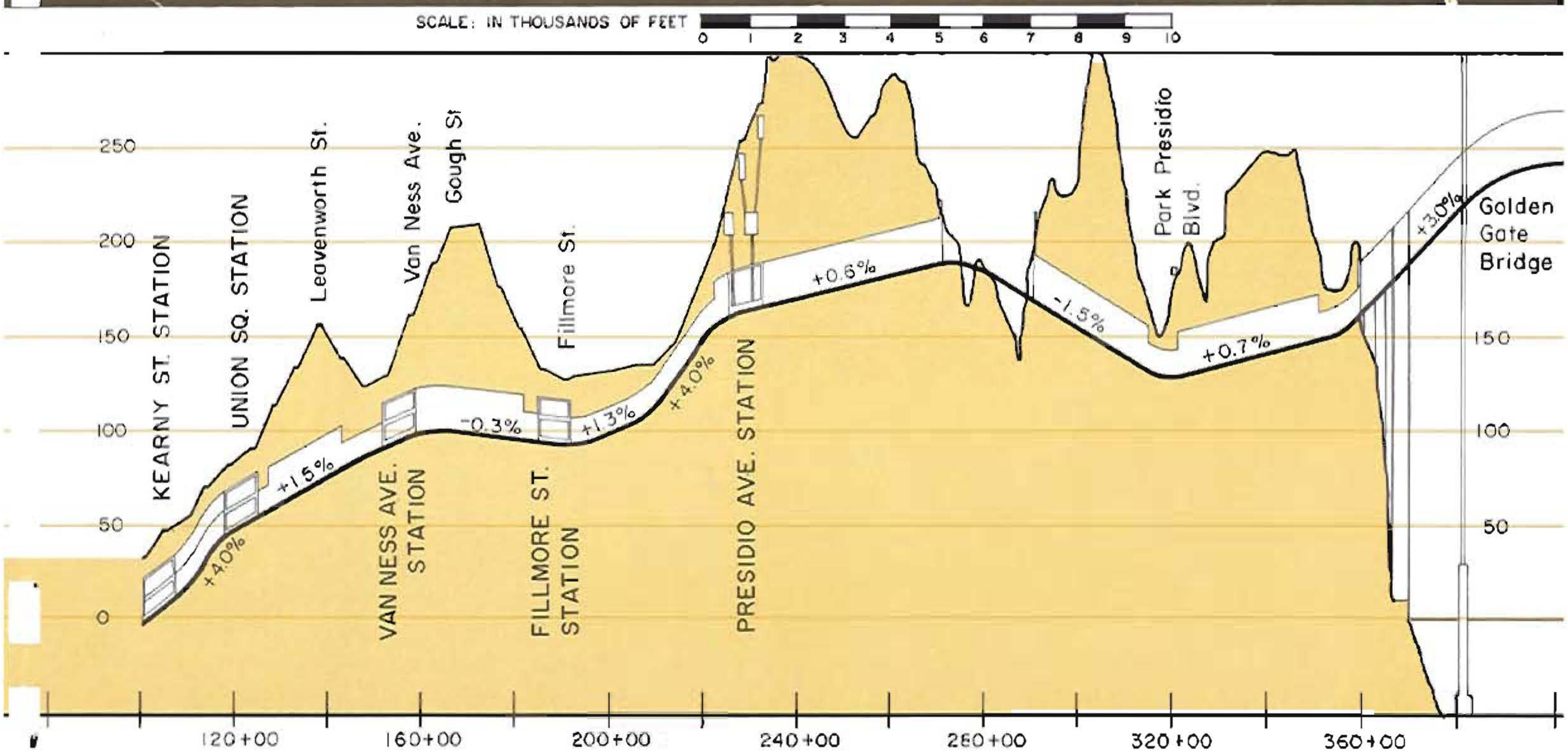
The San Rafael Station is at grade on the west side of the Northwestern Pacific Railroad south of Irwin Street. To reach this site the Marin Line tracks cross over the railroad on aerial structure and descend to grade. North of the station the tracks pass beneath the proposed freeway ramp connections, rise again on aerial structure, and return to the east side of the Northwestern Pacific near 3rd Street.

The line parallels the railroad through the remainder of San Rafael and through a tunnel beneath the Lincoln Avenue interchange. The rapid transit line departs from the railroad alignment and crosses to the east of Merrydale Road, and it parallels Merrydale Road until it rejoins the railroad to cross beneath Route 101 Freeway. The line enters the Santa Venetia Station near the site of the Marin County Government Center. The present phase of rapid transit construction is to be carried to the northern end of the Santa Venetia Station structure and only far enough beyond to permit construction of a transit terminal yard.

In the future, service is to be extended to Ignacio. To achieve this extension of the service in the most economical manner, the purchase of right of way is incorporated in this initial plan. From the Santa Venetia Station to Ignacio, the right of way to be acquired consists of a narrow strip paralleling the Northwestern Pacific Railroad.

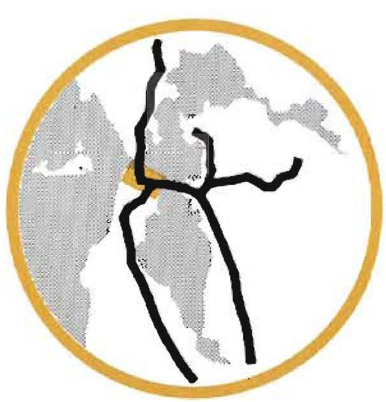
The Marin Line, excluding the San Francisco Downtown connection and the 4.4-mile right-of-way extension, is 19.4 miles long and has seven stations.





SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 9

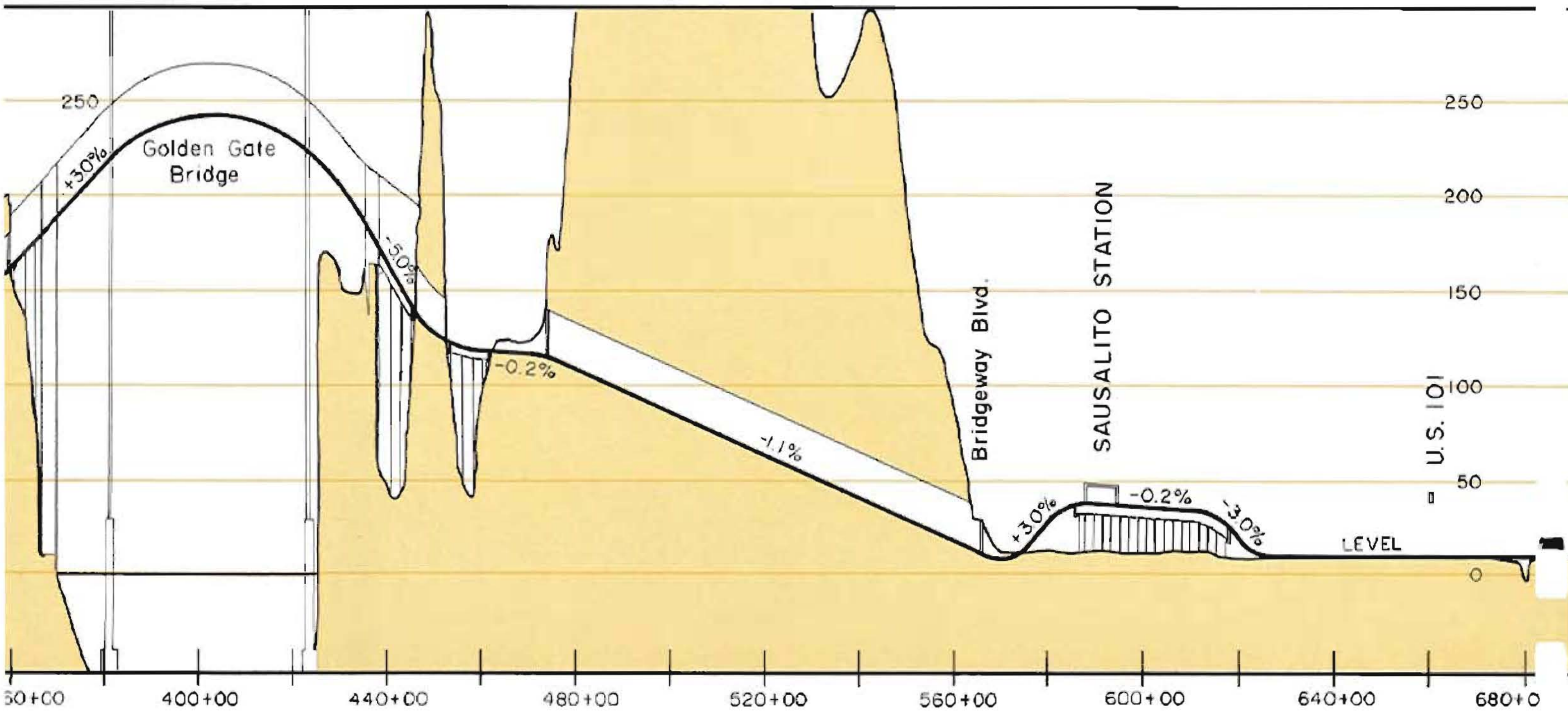


MARIN LINE

STATION 174+00 TO STATION 360+00

INDICATES AREA SHOWN BY THIS PLATE

PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS



SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

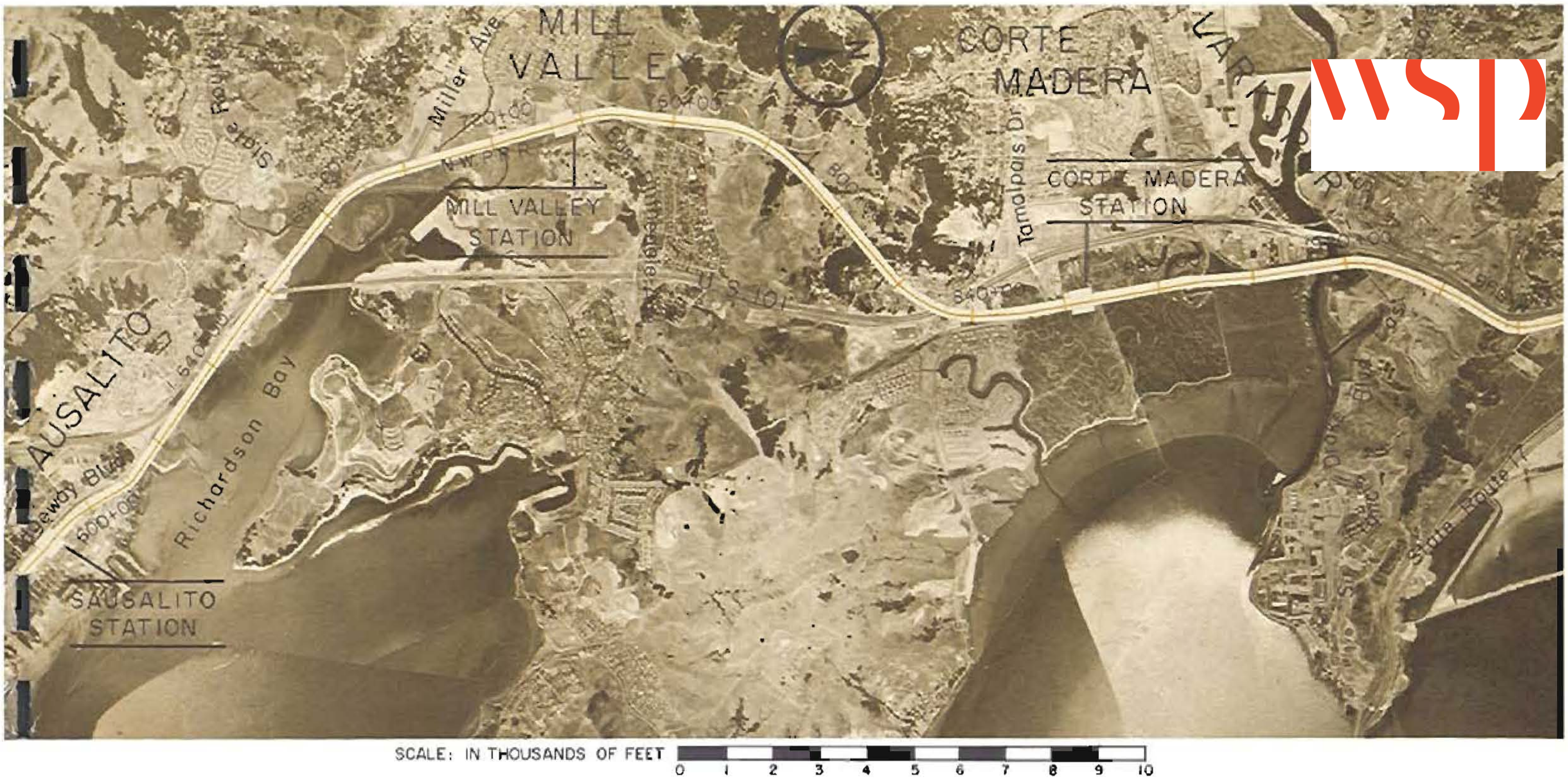
PLATE 10

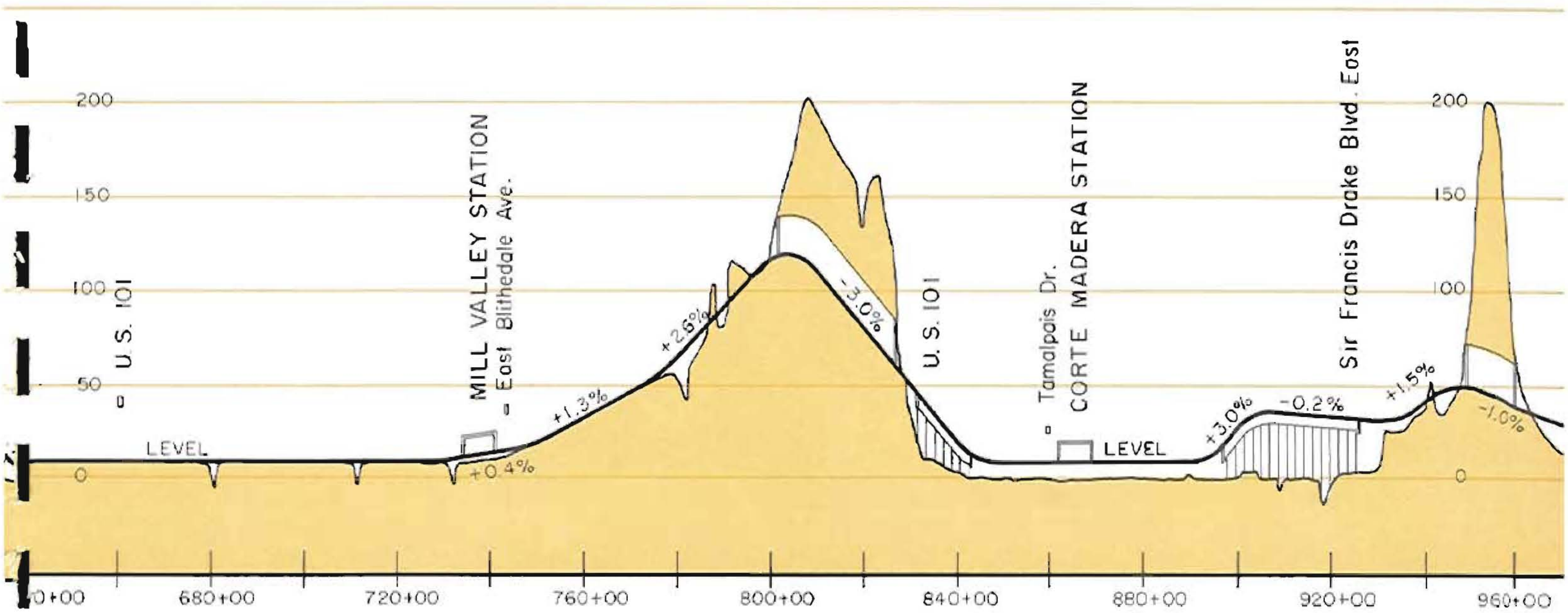
MARIN LINE

STATION 360+00 TO STATION 640+00

INDICATES AREA SHOWN BY THIS PLATE

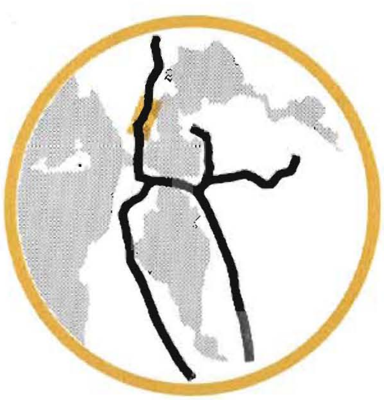
PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS





SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 11

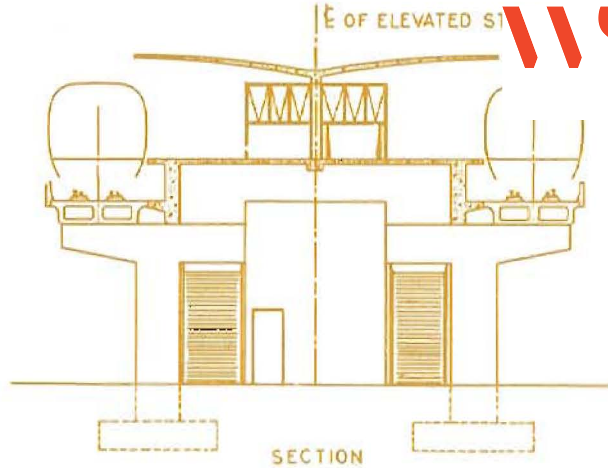


MARIN LINE

STATION 640+00 TO STATION 920+00

INDICATES AREA SHOWN BY THIS PLATE

PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS



BERKELEY-RICHMOND LINE

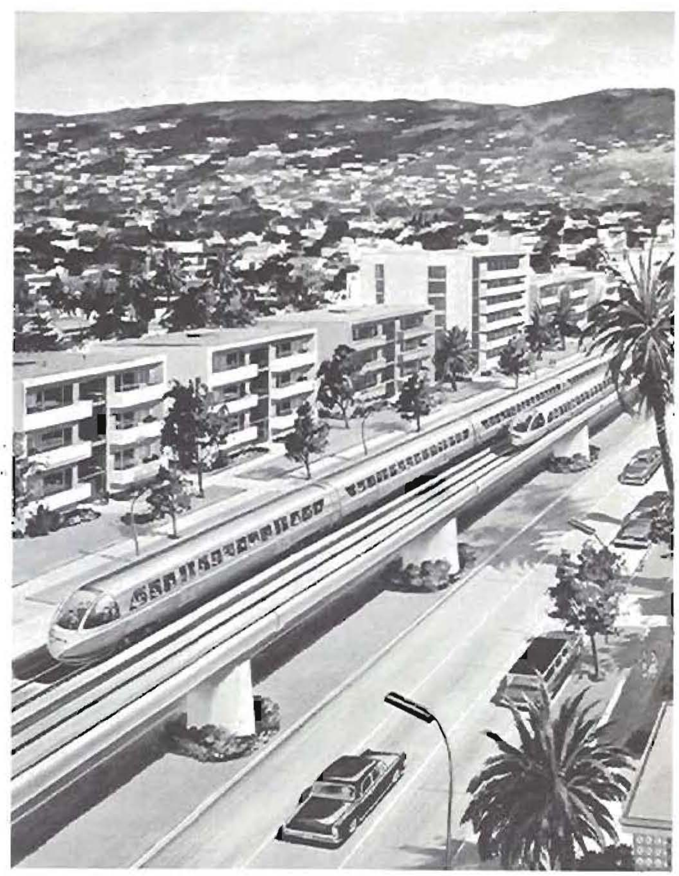
From the northern portal of the Broadway subway, the Berkeley-Richmond Line enters the median of the Grove-Shafter Freeway, passing beneath the northbound freeway lanes. The line, three tracks at this point, continues on embankment or on structure at the same grade as the freeway. At 32nd Street, the rapid transit right of way widens to accommodate a fourth track. All four of these tracks pass beneath the proposed MacArthur Freeway before the center pair of tracks rises on structure to approach the MacArthur Station at 40th Street. This station has two track levels. The lower two tracks continue as the Central Contra Costa Line following the Grove-Shafter Freeway median toward the Berkeley Hills Tunnel. The two tracks to Richmond depart from the upper level of the MacArthur Station and cross over the southbound freeway lanes. Commencing at 45th Street in Oakland, the aerial line proceeds westerly from the freeway to Grove Street.

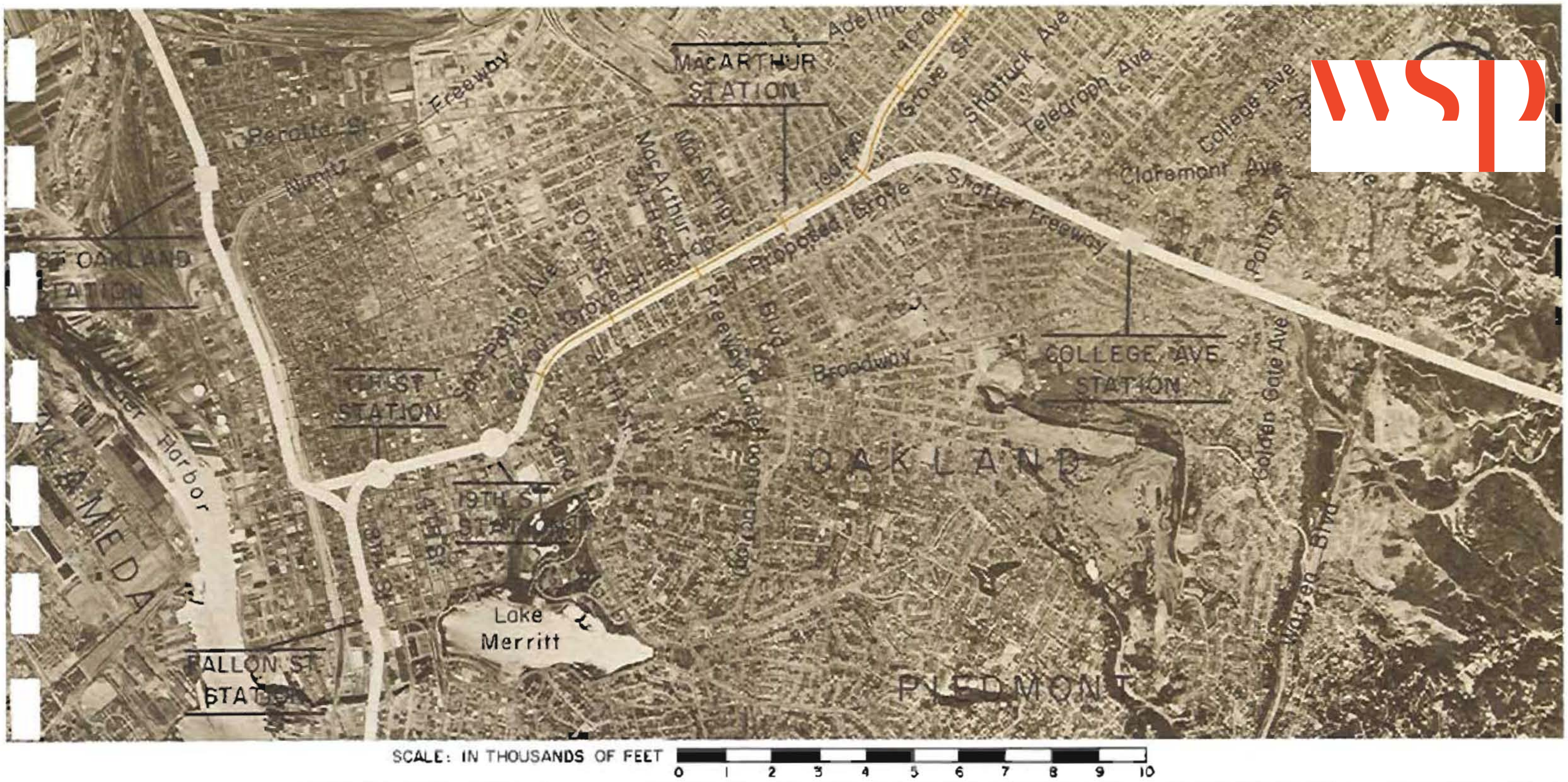
Along Grove Street, from 51st Street to 63rd Street, the aerial transit line is in the street median. The same mode of construction is continued northward along Adeline Street to the Ashby Avenue Station, which is located in the center of the street, approximately midway between Woolsey Street and Ashby Avenue. From the station, the line continues northward along Shattuck Avenue to Derby Street, which marks the beginning of a transition from aerial structure to subway, the subway portal being located at the south side of Dwight Way.

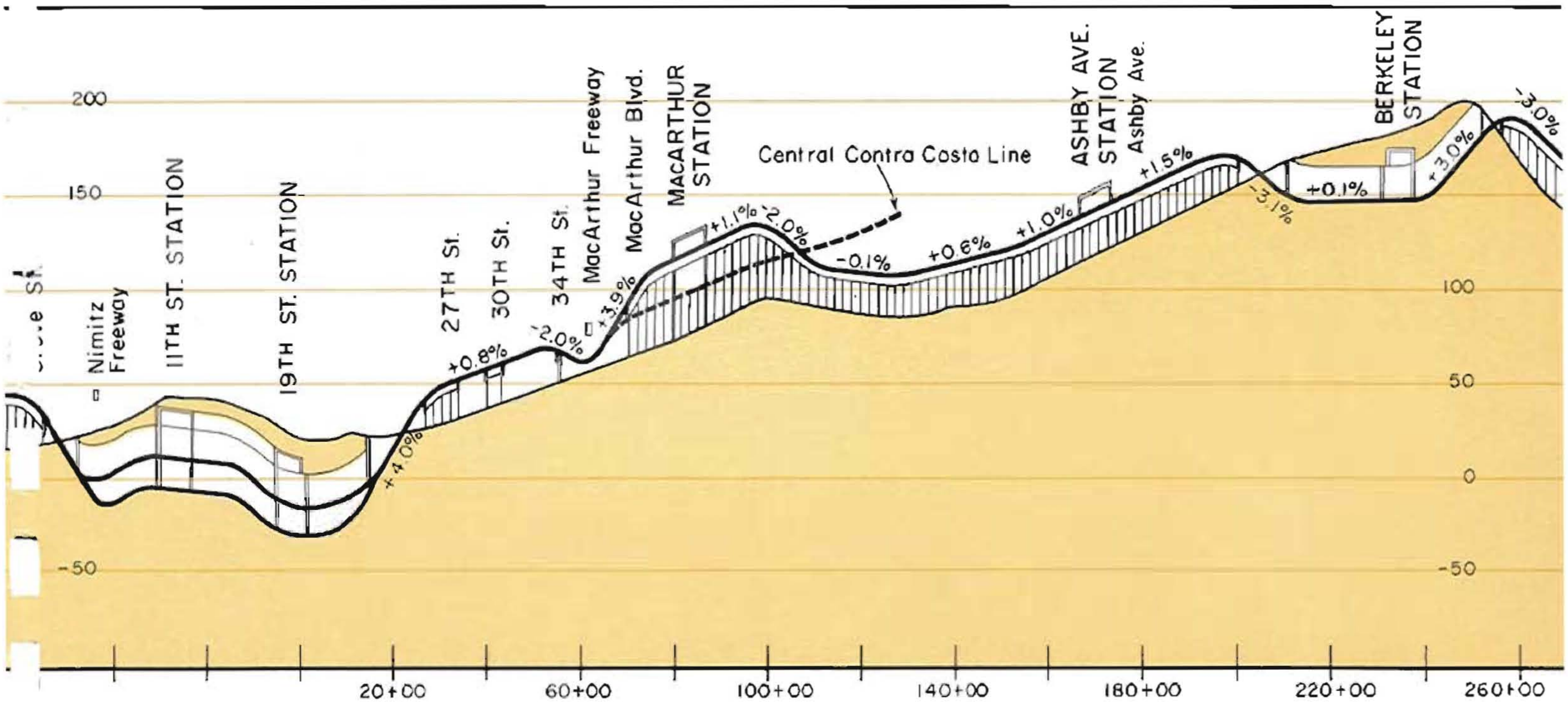
Subway construction is continued throughout central Berkeley, passing through the Berkeley Station at Center Street and emerging from a portal on the west side of Milvia Street. The Milvia Street portal marks the beginning of a transition back to an aerial structure occupying the median of a widened Hearst Avenue to the Sacramento Street Station. The line curves northward at Francisco Street to join the Atchison, Topeka and Santa Fe Railroad right of way, and from this point, construction consists of aerial structure along the west side of the railroad. Stations are located at Fairmont Avenue and immediately south of Cutting Boulevard in El Cerrito.

The route continues to parallel the Santa Fe right of way, passing beneath the Eastshore Freeway and remaining to the south of the railroad. Construction alongside the railroad is an embankment. At 10th Street the line crosses over the Santa Fe tracks on aerial structure and turns into the Richmond Station at Macdonald Avenue between 5th and 6th Streets in Richmond. North of the station, the line descends to grade to enter the maintenance and storage yard adjacent to Pennsylvania Avenue.

The Berkeley-Richmond Line is 12.8 miles long and has seven stations.

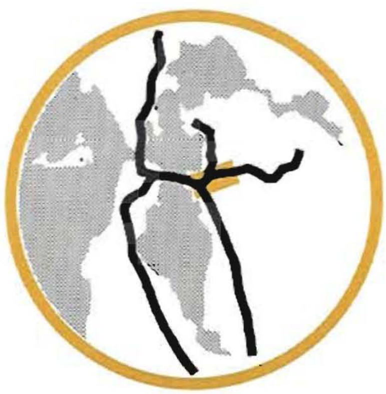






SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 16



BERKELEY-RICHMOND LINE

STATION 16+00 TO STATION 100+00

INDICATES AREA SHOWN BY THIS PLATE

PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS

CENTRAL CONTRA COSTA LINE

Beginning in downtown Oakland, the rapid transit tracks to central Contra Costa County and to Richmond occupy the median of the Grove-Shafter Freeway as a part of the Berkeley-Richmond Line. North of the MacArthur Station, the lines separate and the Berkeley-Richmond Line continues to the north while the Central Contra Costa Line remains at grade in the median of the elevated freeway. An aerial station is provided at College Avenue.

The line continues in the median of the Grove-Shafter Freeway to Patton Street where the rapid transit tracks leave the freeway by crossing in subway under the westbound freeway lanes and entering a 3.3-mile tunnel to the north of, and far below, the existing Caldecott Tunnel. After entering Contra Costa County and emerging from the tunnel at the Orinda Station, the line passes on aerial structure over the ramps of the State Route 24-Camino Pablo interchange.

Proceeding easterly, the line remains on the north side and parallel to the freeway to the Acalanes Boulevard interchange. Construction is at grade except for a tunnel under the crest of the hill at Charles Hill Road. The line bridges over the ramps of the Acalanes Boulevard interchange, Upper Happy Valley Road, and Sunnybrook Drive. The tracks then pass under the State Route 24 grade-separation structure and proceed generally on embankment between Mt. Diablo Boulevard and the freeway into Lafayette. The line changes to structure adjacent to the East Bay Municipal Utility District pumping plant and then continues on graded section along the south edge of the freeway to the Lafayette Station.

Immediately east of the Lafayette Station, the route curves to the southeast, crossing over Mt. Diablo Boulevard, Golden Gate Way and Moraga Boulevard to join the proposed Olympic Boulevard alignment along the abandoned Sacramento Northern Railway right of way. Olympic Boulevard will probably be developed initially as a two-lane street and later expanded to four lanes. The rapid transit line is on aerial structure along the northerly side of the original two lanes but is planned so that it will be in the median of the future four-lane thoroughfare.

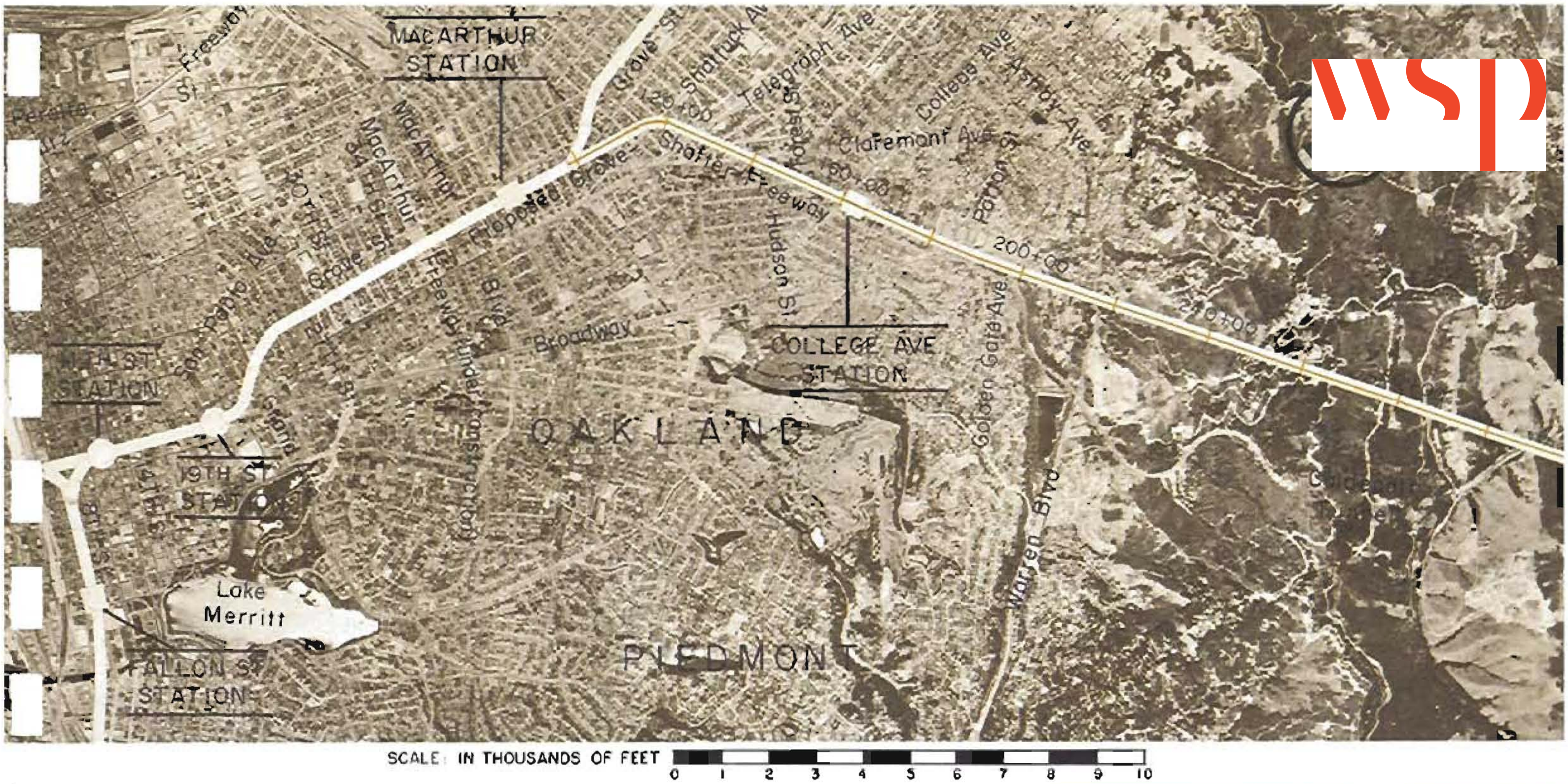
Just before passing under the State Route 21 Freeway, through the Majon Way grade-separation structure, the line leaves the median and shifts to the north of the westbound lanes of Olympic Boulevard to enter the Walnut Creek Station. The station is located between the freeway and South California Avenue.

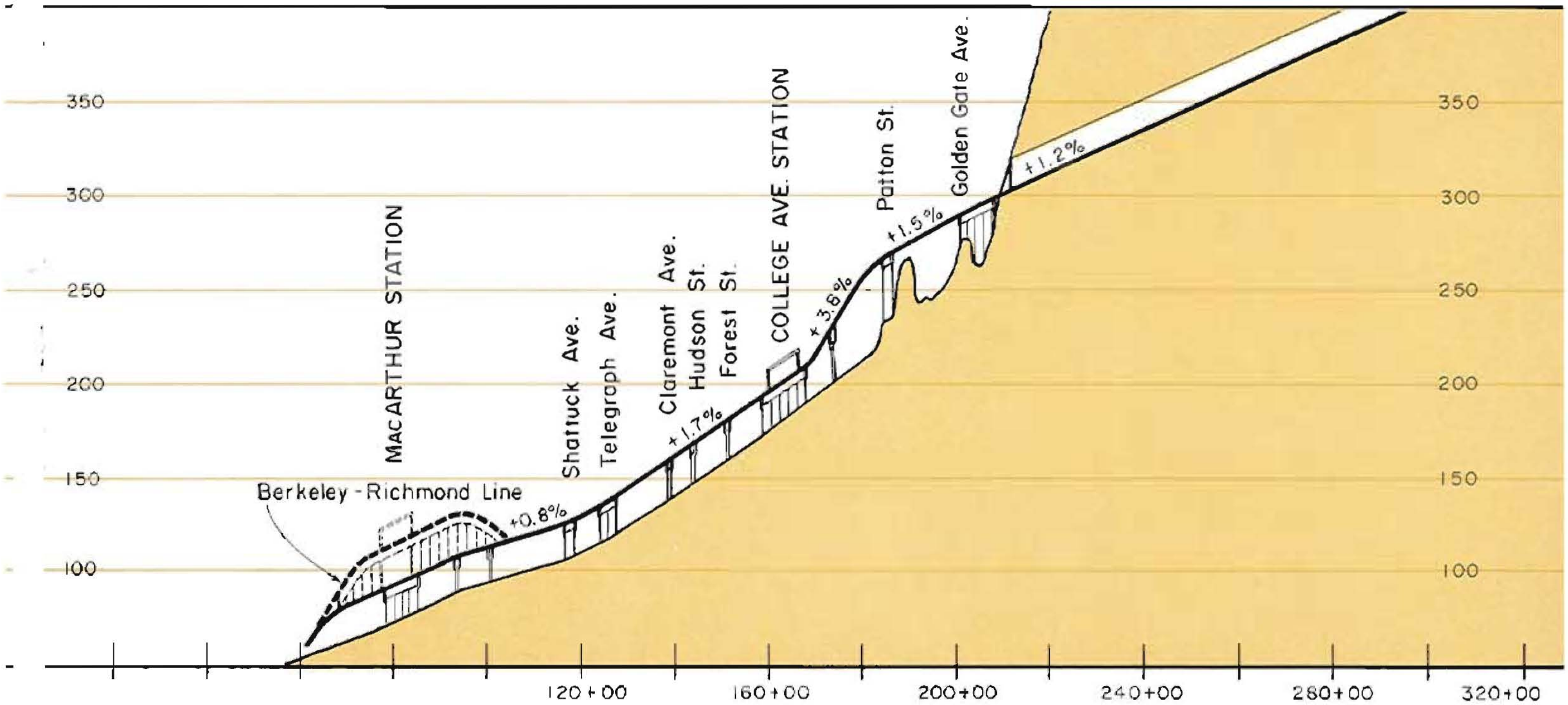
East of the Walnut Creek Station the line passes over Mt. Diablo Boulevard and continues on aerial structure along the Sacramento Northern Railway right of way. Crossing over Ygnacio Valley Road, it then proceeds at grade and on embankment, except for street-separation structures. After crossing under Geary Road the line rises and utilizes aerial construction to the Pleasant Hill Station in Walden. A transit car storage yard is located between the Pleasant Hill Station and the Concord Station.

Beyond the Pleasant Hill Station the line descends to grade after crossing over the Southern Pacific tracks. Structures provide for Bancroft and Oak Grove Roads to cross over the rapid transit tracks. The line remains at grade until it again rises to cross San Miguel Road.

Since it is assumed that the Sacramento Northern Railway will continue operations north and east of Oak Grove Road, the rapid transit tracks are at grade parallel to and east of the railroad to San Miguel Road and then ascend to aerial structure and proceed into the Concord Station at Clayton Road.

The Central Contra Costa Line is 19.9 miles long and includes six stations.





SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

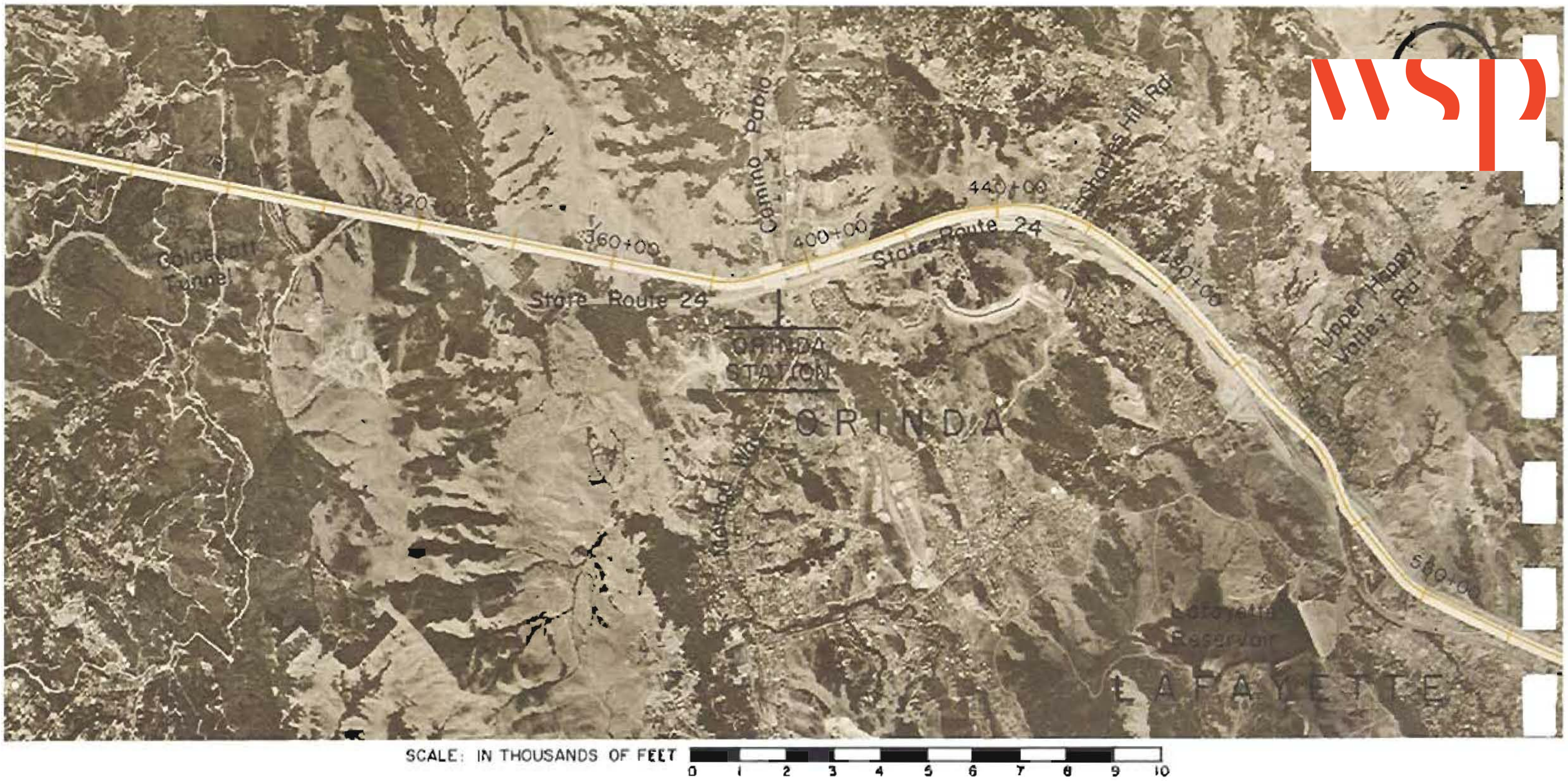
PLATE 19

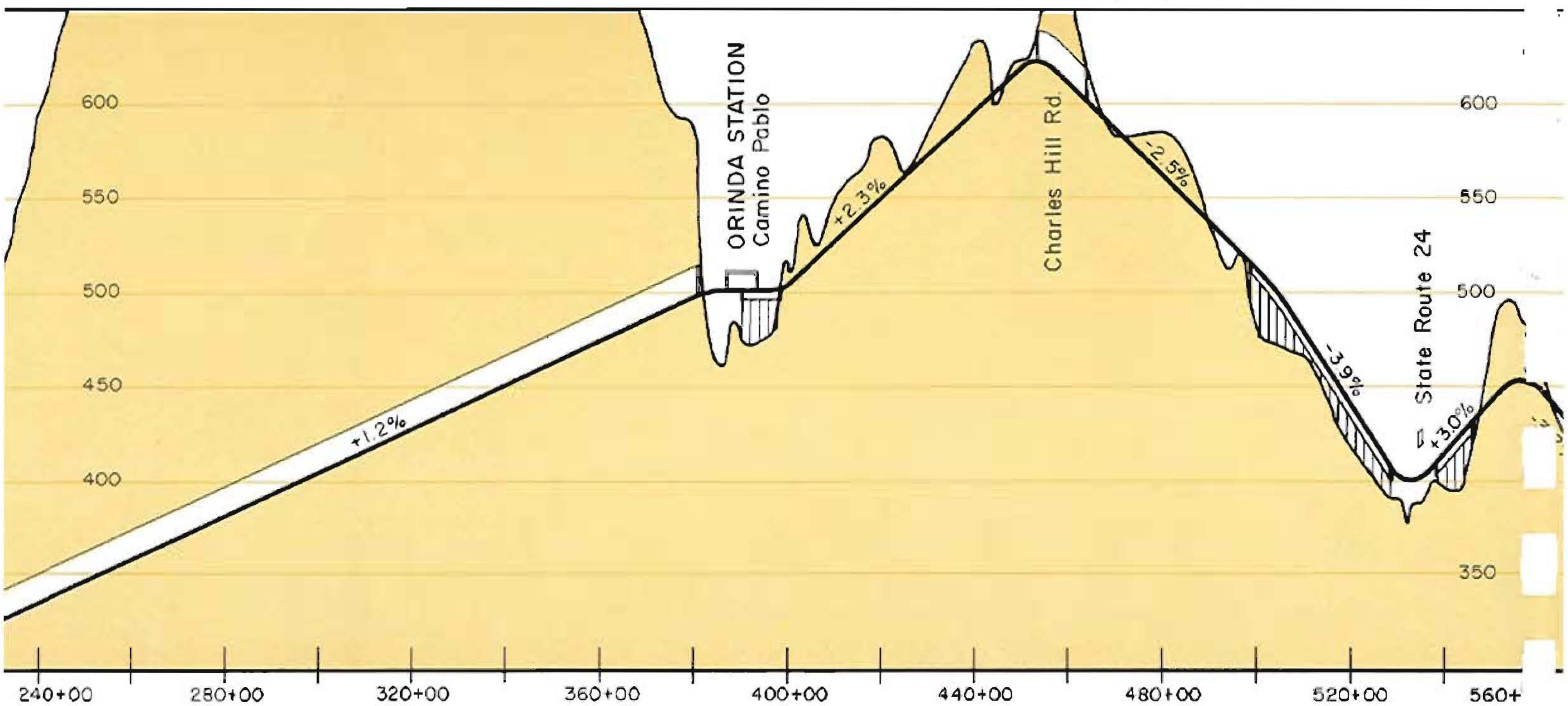
CENTRAL
CONTRA COSTA LINE

STATION 96+00 TO STATION 280+00

INDICATES AREA SHOWN BY THIS PLATE

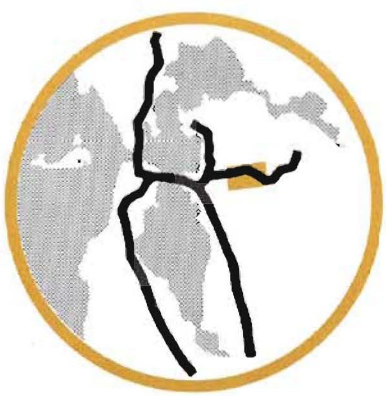
PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS





SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 20

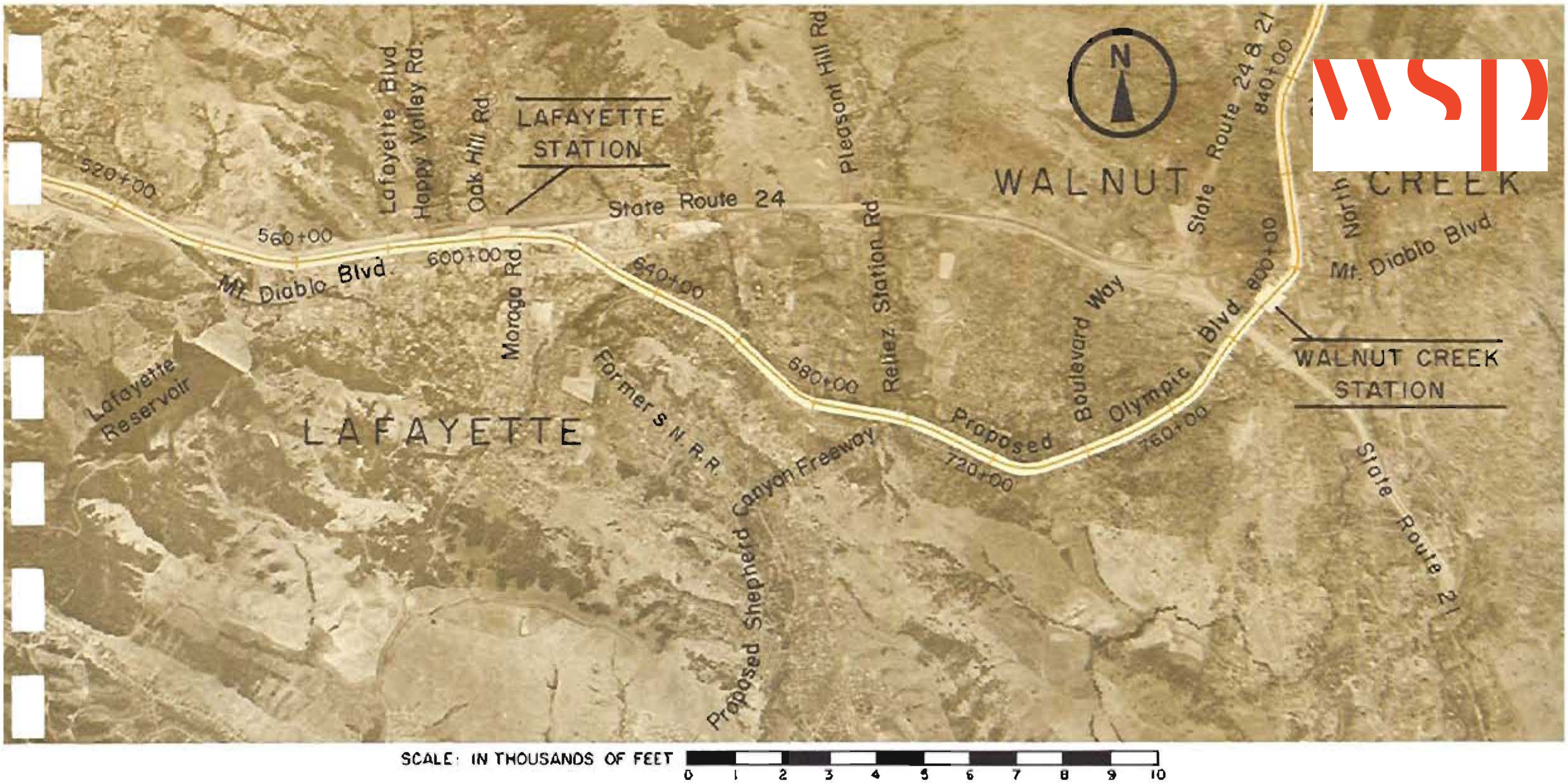


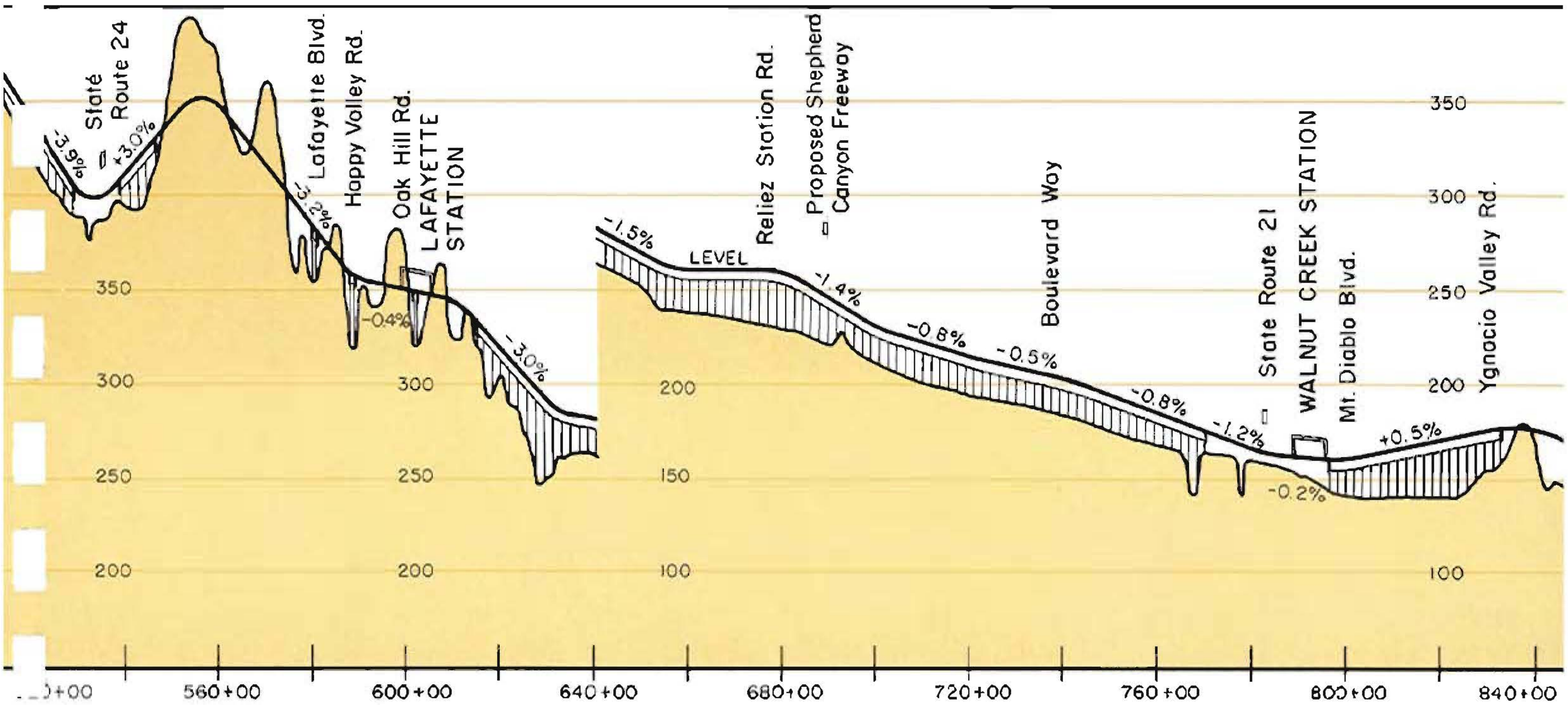
CENTRAL
CONTRA COSTA LINE

STATION 280+00 TO STATION 560+00

INDICATES AREA SHOWN BY THIS PLATE

PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS





SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 21

CENTRAL
CONTRA COSTA LINE

STATION 560+00 TO STATION 840+00

INDICATES AREA SHOWN BY THIS PLATE

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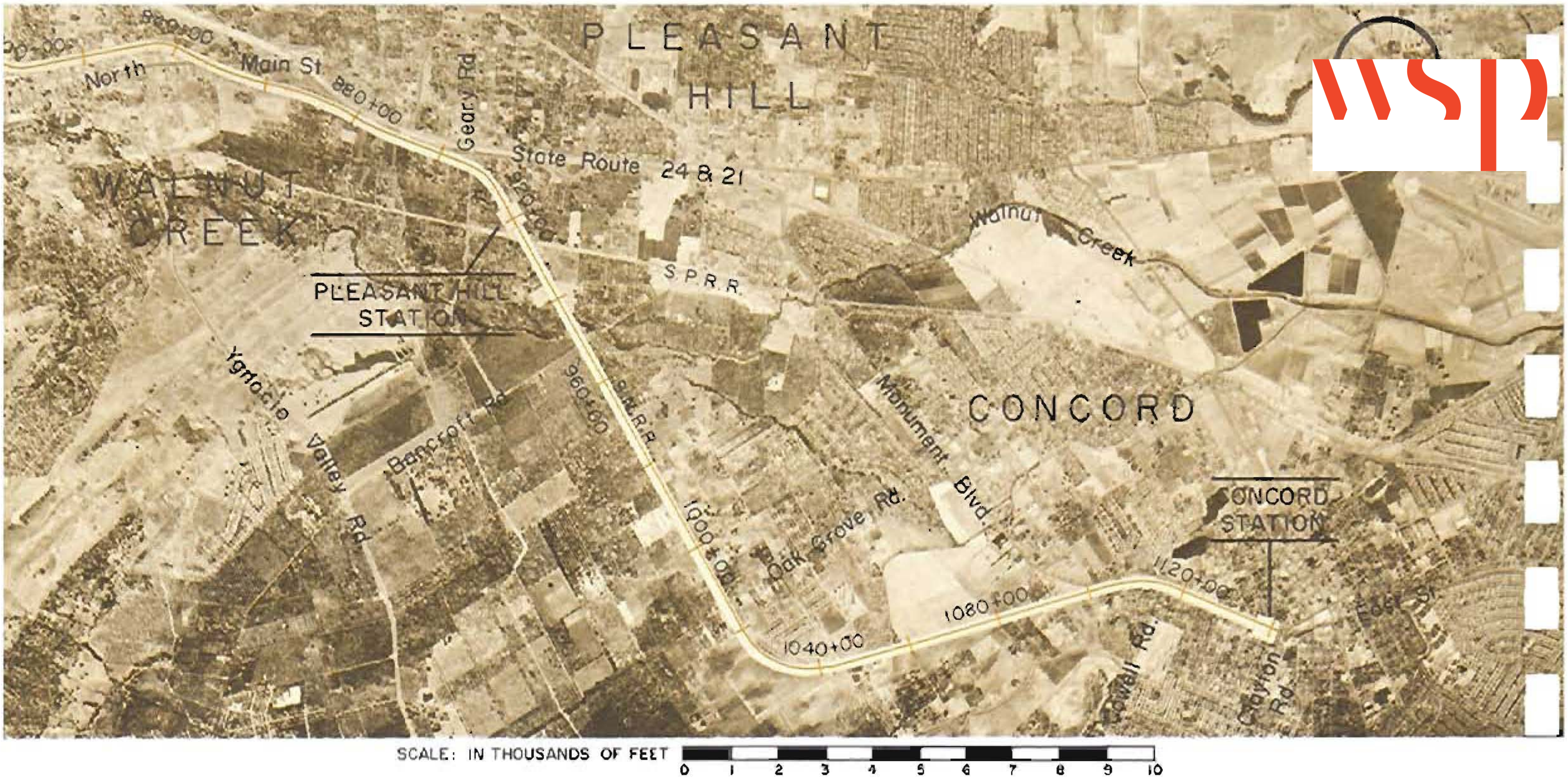

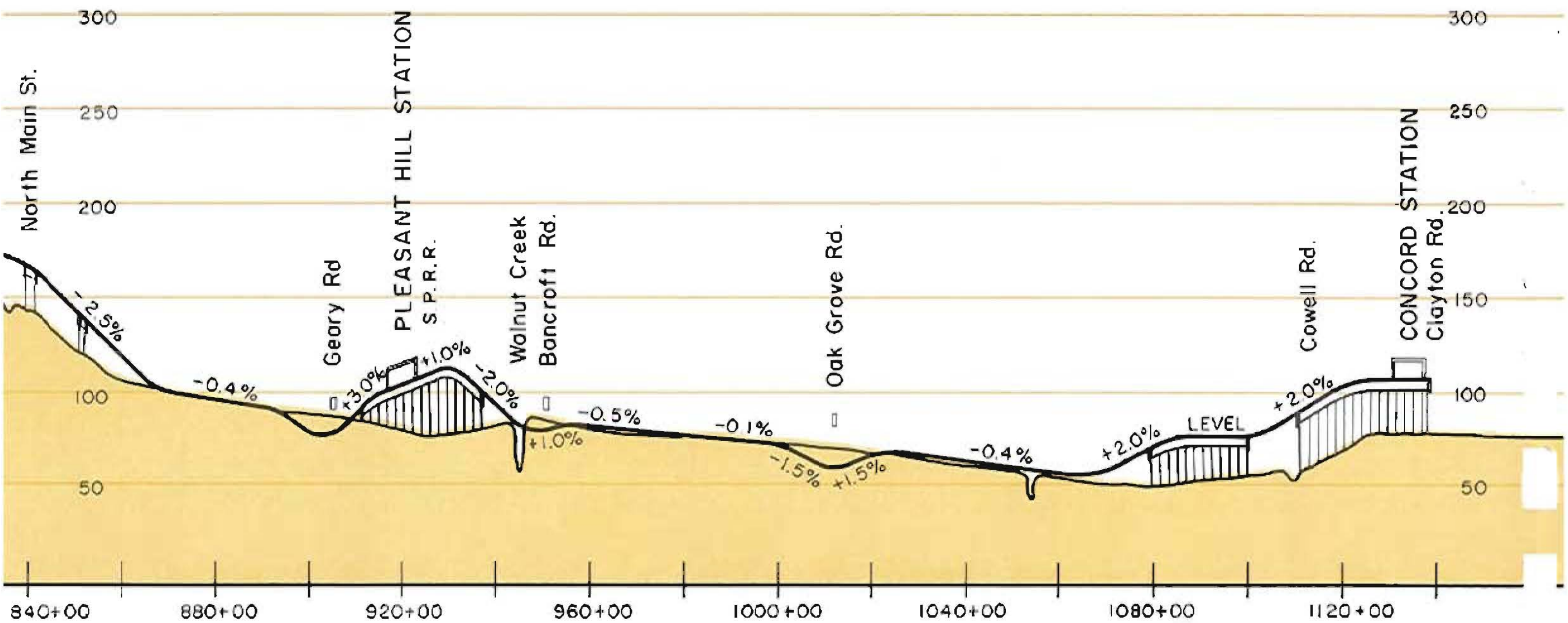

SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 22

CENTRAL
CONTRA COSTA LINE

STATION 840+00 TO STATION 1140+00

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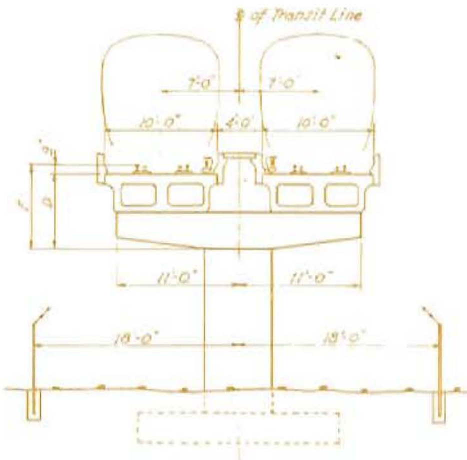
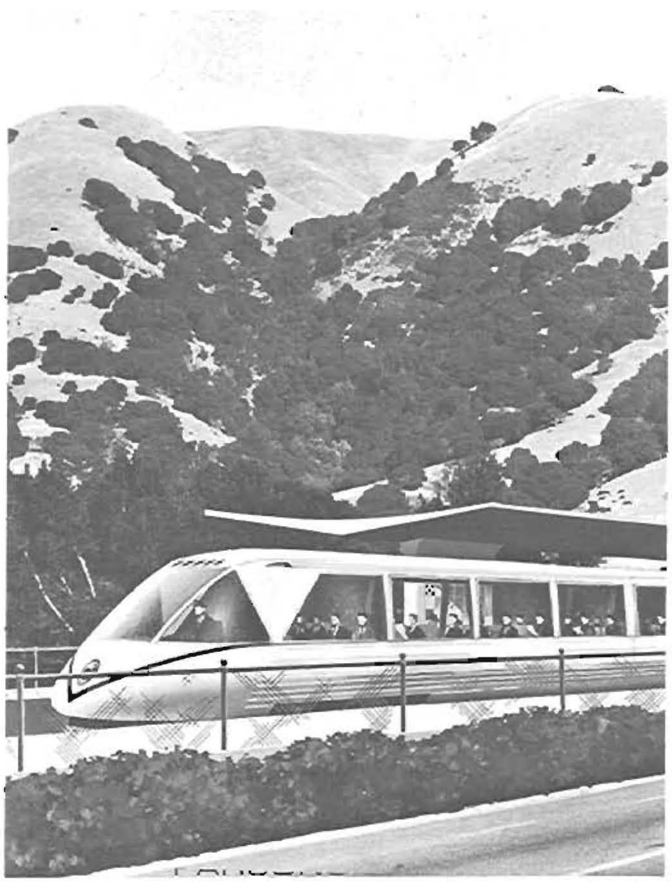


SOUTHERN ALAMEDA COUNTY LINE

The connection to the Southern Alameda County Line in Oakland Downtown is a two-track subway in 8th Street, extending from Broadway and the 11th Street Station through the Fallon Street Station. This connection is estimated as a part of the Oakland Downtown segment.

The Southern Alameda County Line begins near the Exposition Building and beyond the Fallon Street Station. Proceeding southward the subway leaves the alignment of 8th Street, passes beneath the channel of Lake Merritt Inlet, and then follows 7th Street. After passing beneath 5th Avenue, the tracks come to the surface along the east side of the Western Pacific Railroad main line tracks. The rapid transit tracks remain on grade along the railroad until they pass beneath the 19th Avenue overcrossing where they rise on aerial structure and enter the median of East 12th Street. The line continues in this median to Fruitvale Avenue. Both the Fruitvale Avenue Station at 36th Avenue and the transit line southward to 47th Avenue are located immediately east of the Western Pacific tracks.

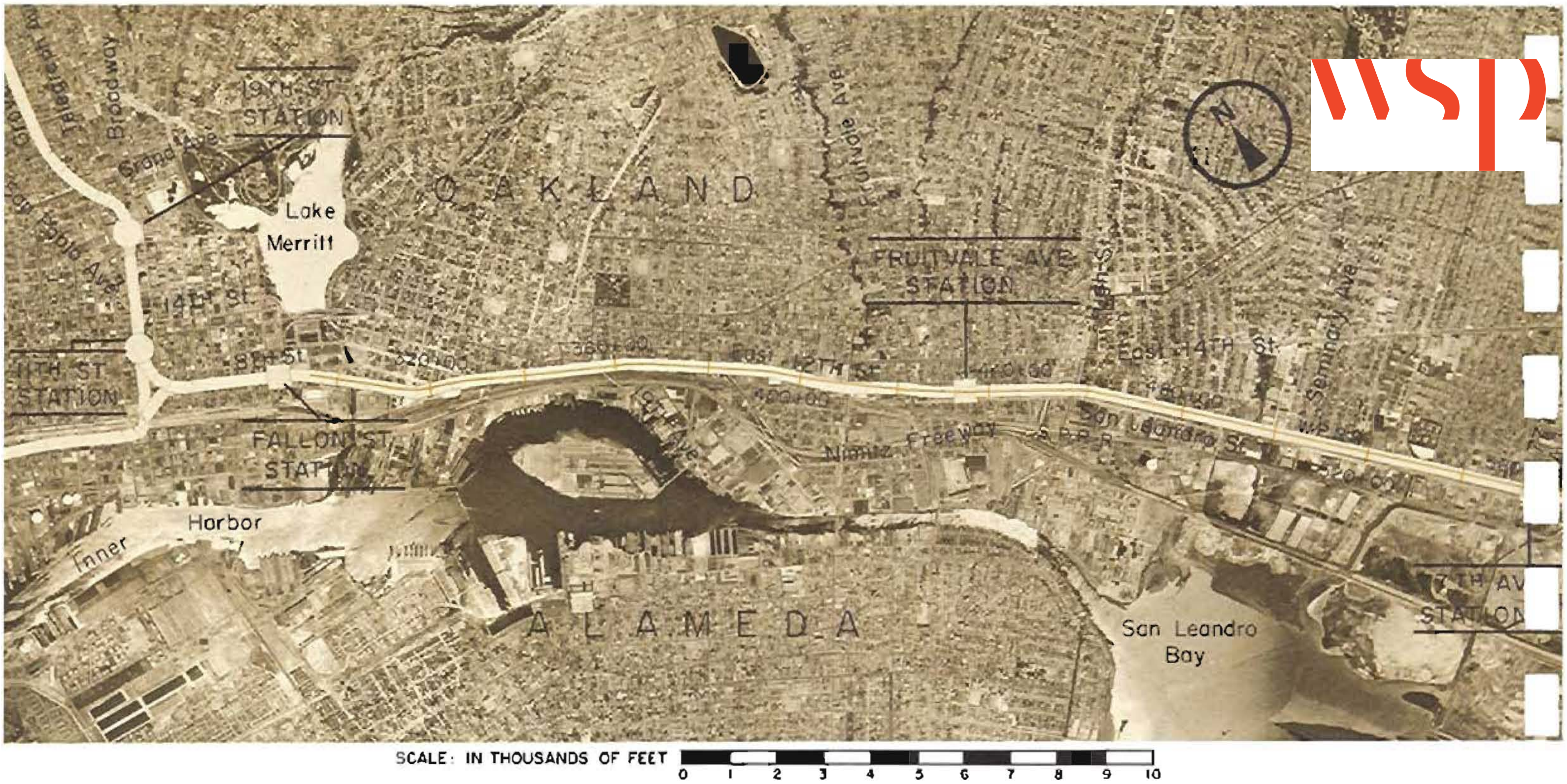


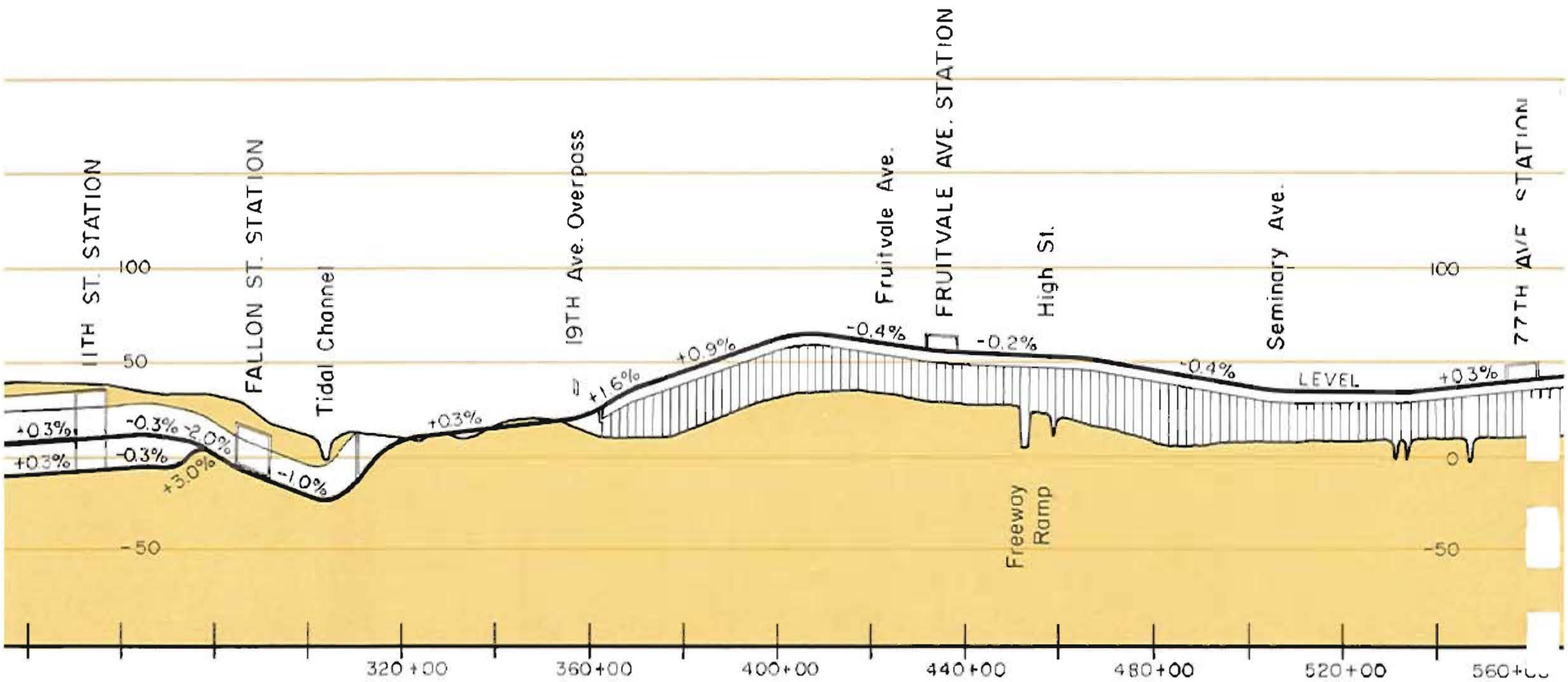
At 47th Avenue, the line crosses the Western Pacific tracks to occupy a narrow strip between the railroad and San Leandro Street. The line continues to follow this strip, on aerial structure to 105th Avenue with a station at 77th Avenue. At 105th Avenue, the structure once again crosses to the east side of the Western Pacific tracks, remaining there as far as Hayward. The aerial San Leandro Station is located at Davis Street. The line continues on structure through San Leandro, and the next station is located at Hesperian Boulevard. U. S. Highway 50 provides automobile access to the Hesperian Boulevard Station. The rapid transit tracks descend to grade to pass under the existing U. S. Highway 50 structure. Aerial construction resumes and continues through Hayward. The Hayward Station is located just north of Jackson Street.

The route crosses to the west of the Western Pacific Railroad immediately south of Jackson Street and parallels the railroad. A station is provided at Alquire Road, and the Union City Station is located at Decoto Road. Storage and maintenance facilities are provided at Decoto Road.

At Alameda Creek, about four miles south of Decoto Road, the Western Pacific tracks turn eastward through Niles Canyon. At this point the rapid transit line curves southward away from the railroad to a terminal station in Fremont at Mowry Avenue near the Washington Township Hospital. The Fremont Station is oriented to serve the future urban core as planned in the Fremont General Plan.

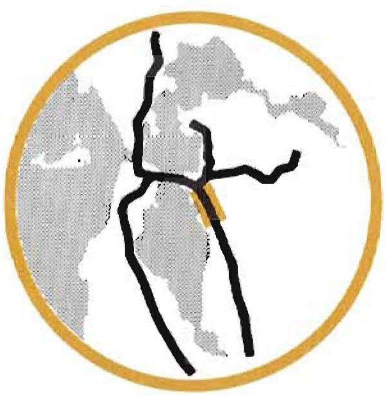
The Southern Alameda County Line is 23.0 miles long, excluding the connection in Oakland Downtown, and contains eight stations.





SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 23



SOUTHERN
ALAMEDA COUNTY LINE

STATION 290+00 TO STATION 520+00

INDICATES AREA SHOWN BY THIS PLATE

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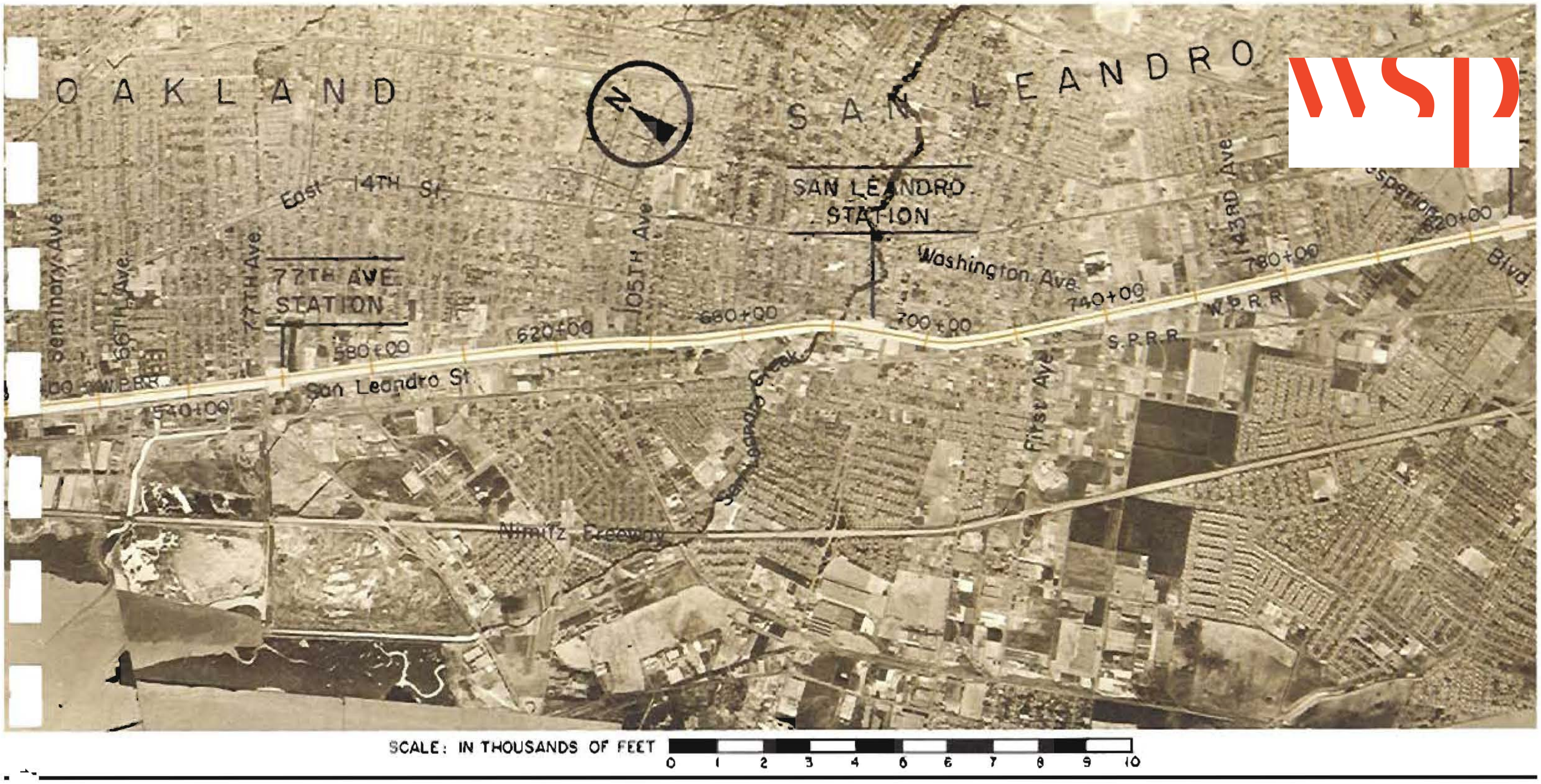
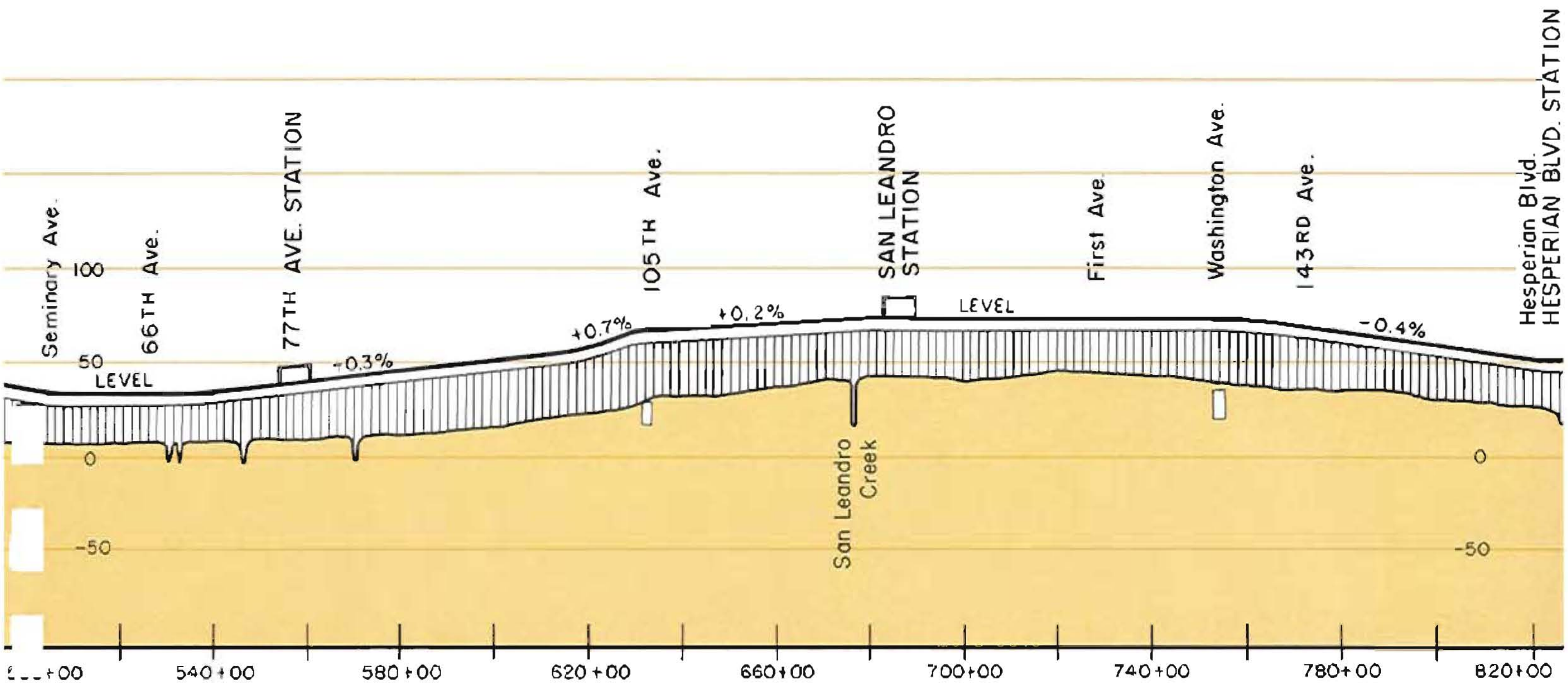
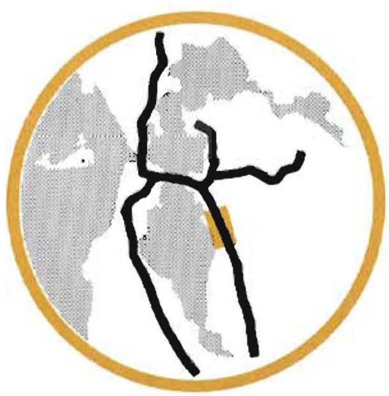




SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 24



SOUTHERN
ALAMEDA COUNTY LINE

STATION 520+00 TO STATION 800+00

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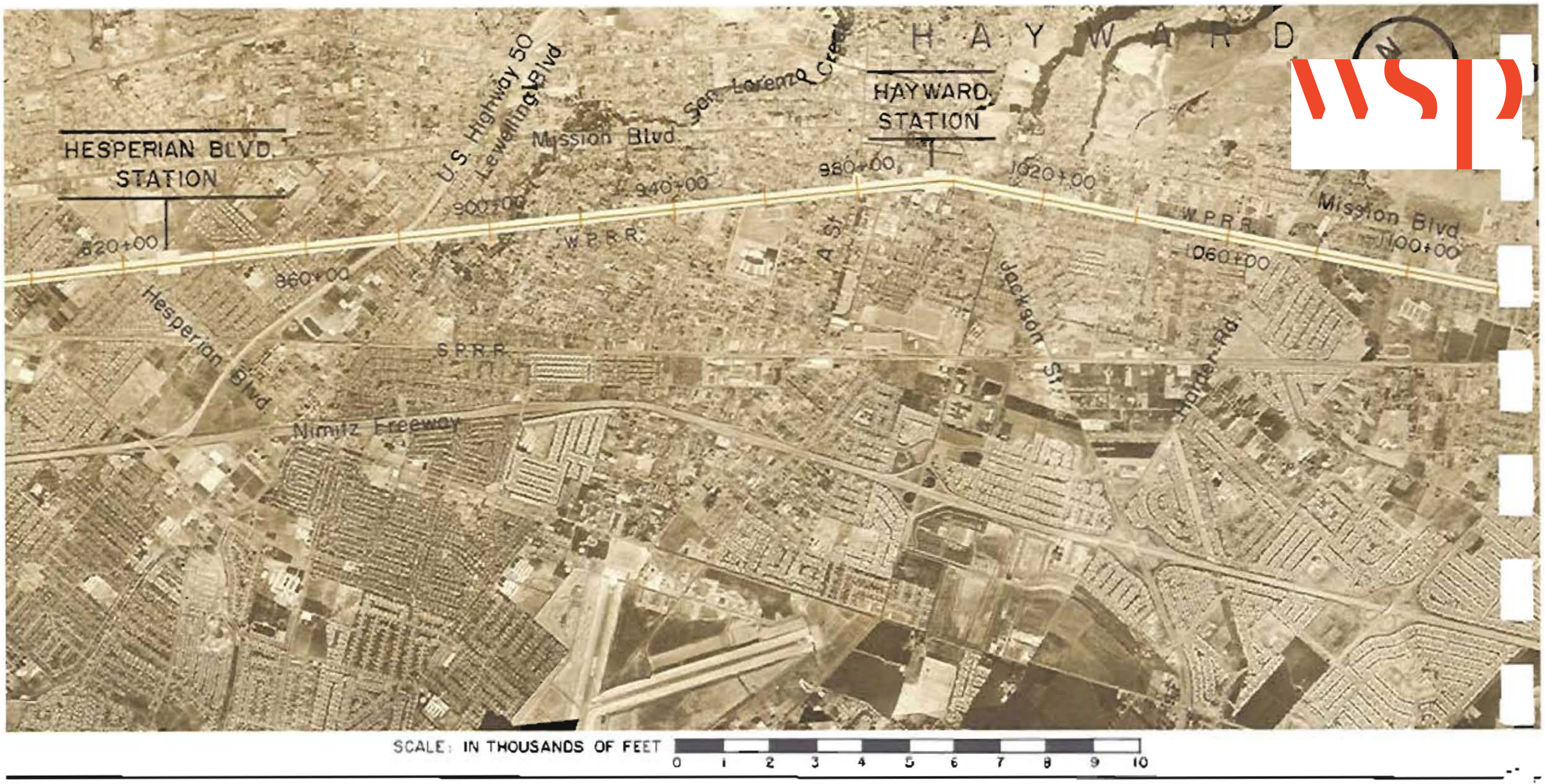
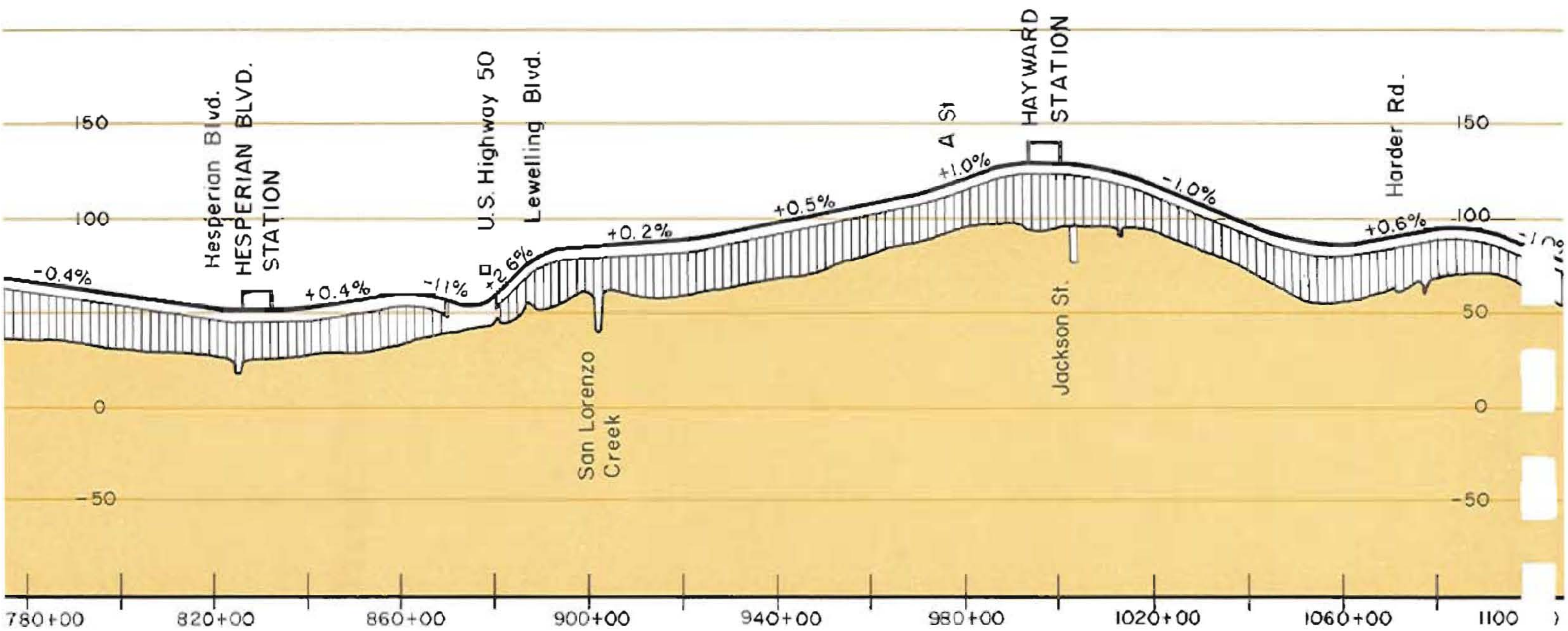




SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

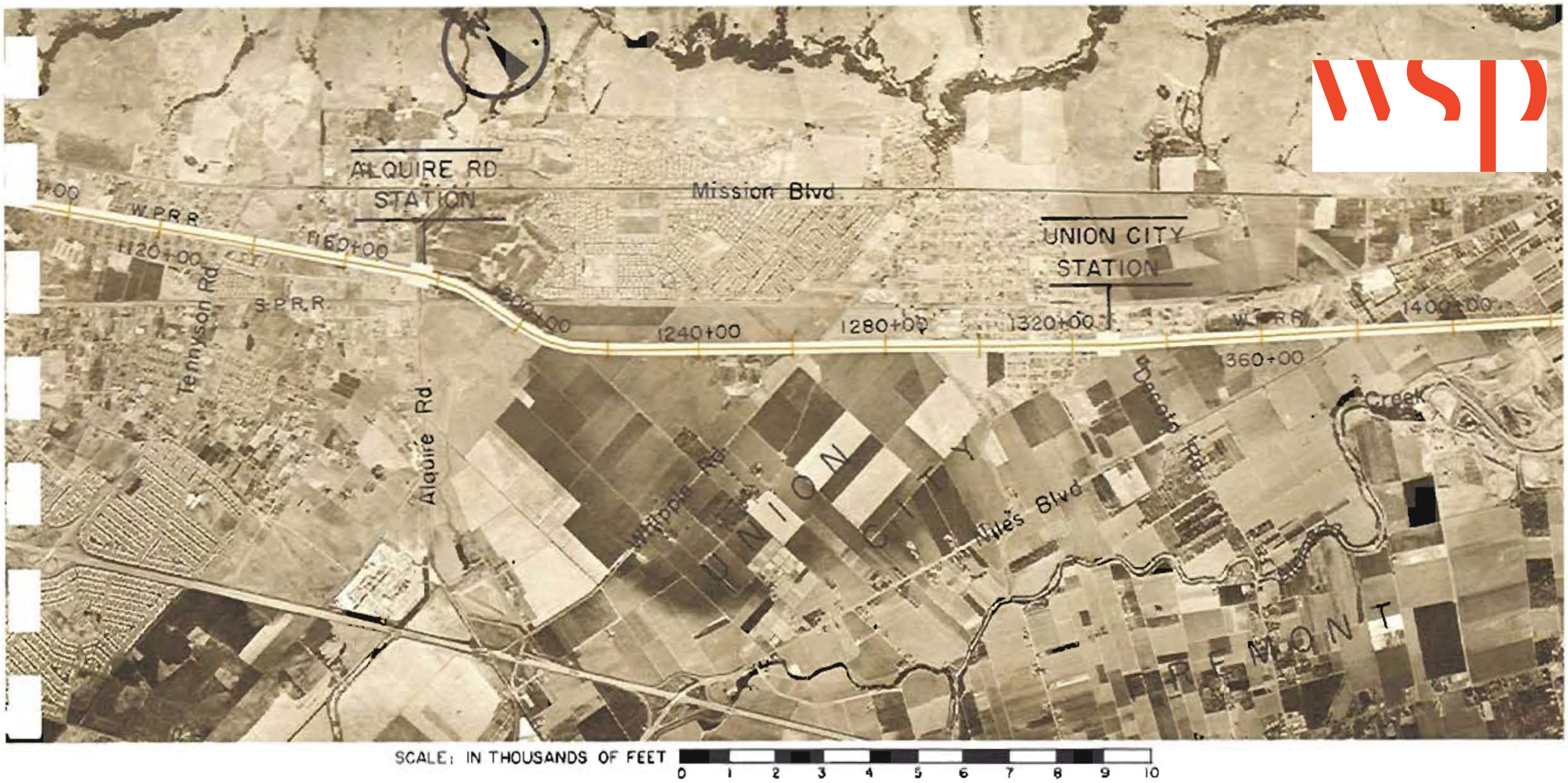
PLATE 25

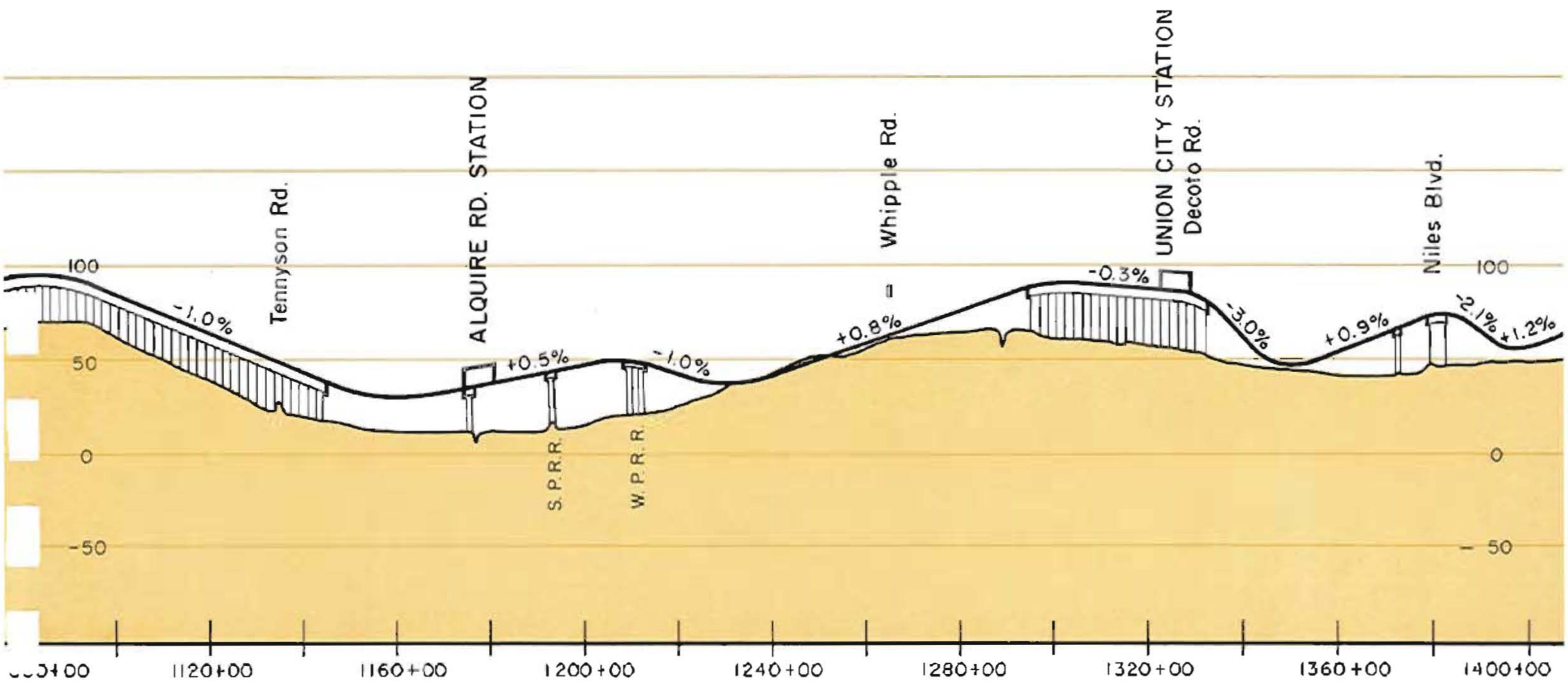
SOUTHERN
ALAMEDA COUNTY LINE

STATION 800+00 TO STATION 1100+00

INDICATES AREA SHOWN BY THIS PLATE

PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS





SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 26

SOUTHERN
ALAMEDA COUNTY LINE

STATION 1100+00 TO STATION 1360+00

INDICATES AREA SHOWN BY THIS PLATE

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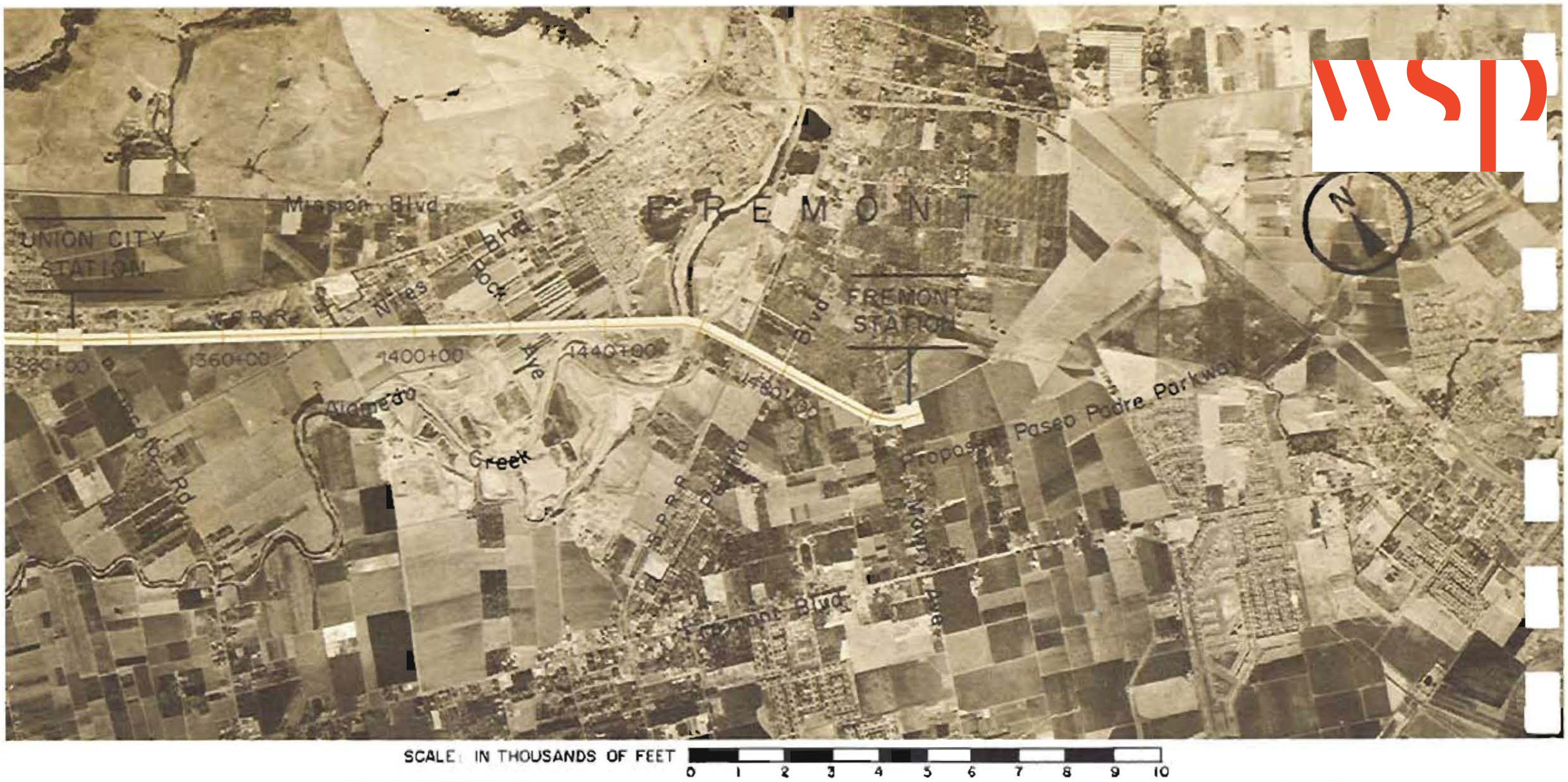
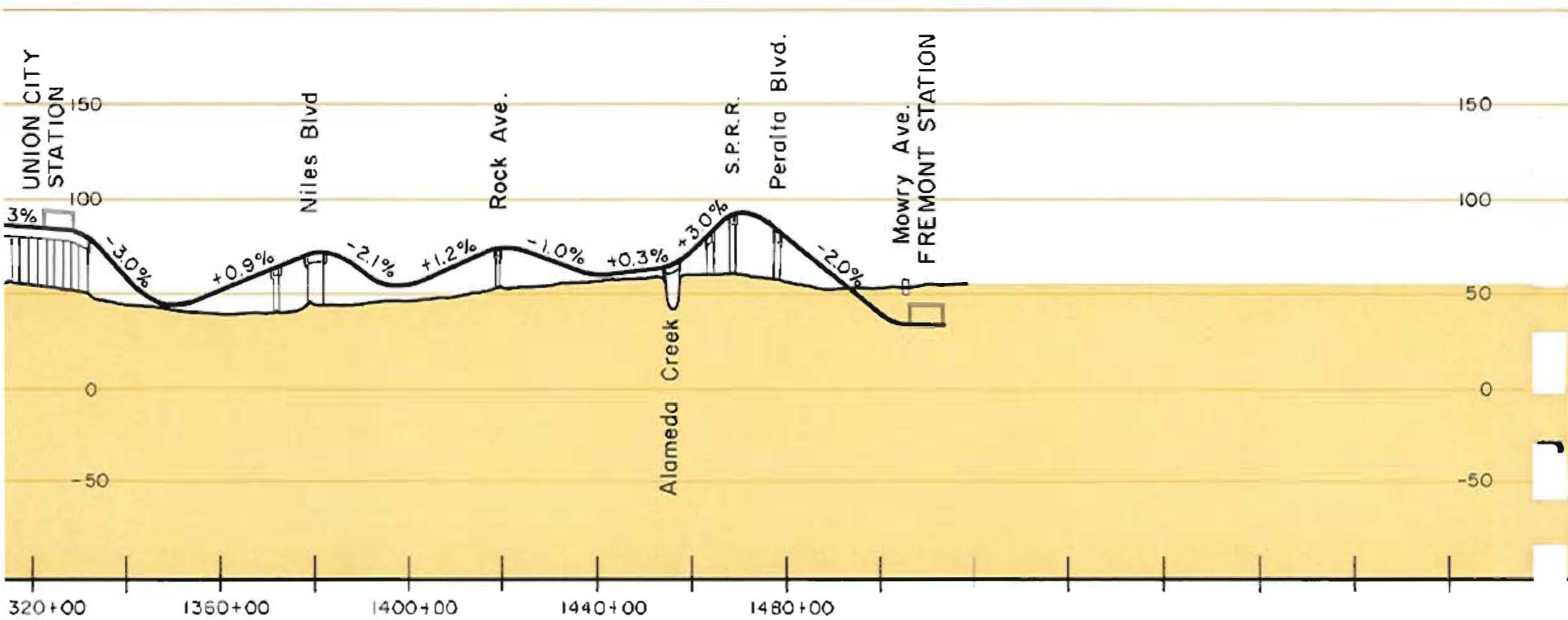
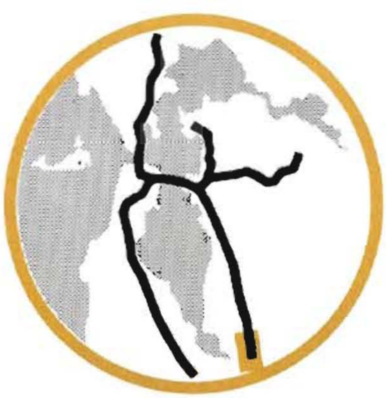




SAN FRANCISCO BAY AREA
RAPID TRANSIT DISTRICT

PLATE 27



SOUTHERN
ALAMEDA COUNTY LINE

STATION 1360+00 TO STATION 1510+00

INDICATES AREA SHOWN BY THIS PLATE

PARSONS BRINCKERHOFF · TUDOR · BECHTEL, ENGINEERS

ESTIMATES

SHEET NO.
X-8
SCALE: None
DATE: Nov 9, 195
FILE NO.
DIV STOP
DIV
NEG MULT
ACC MULT
PILING
CONCRETE, BENT FOOTINGS
CONCRETE, ABUTMENT
CONCRETE, PIERS
CONCRETE, PARAPET AND WALKWAY
PRESTRESSED CONCRETE, 60' GIRDERS
PRESTRESSED CONCRETE, 80' GIRDERS
PRESTRESSED CONCRETE, 100' GIRDERS
PRESTRESSED CONCRETE, SPECIAL GIRDERS
PRESTRESSED CONCRETE, BENT CAPS FOR 60' SPAN
PRESTRESSED CONCRETE, BENT CAPS FOR 80' SPAN
PRESTRESSED CONCRETE, BENT CAPS FOR 100' SPAN
REINFORCING STEEL (EXCLUDING PRESTRESSED MEMBERS)
MISCELLANEOUS METAL
ANCHOR BOLTS
DRAINAGE
TRACK
TRAFFIC ISLANDS
TRAFFIC MAINTENANCE
STREET WIDENING
STRUCTURAL EXCAVATION
STRUCTURAL BACKFILL
FENCE

CONSTRUCTION COSTS

As a part of these studies, an estimate was made of the cost to construct a transit system of the extent and quality depicted in the preceding sections. The estimate takes into account such significant physical factors as route alignment and grade, type of construction, geological conditions, underpinning requirements, traffic maintenance, utility relocation, rights of way, and special problems of grade separation. It is based on recent San Francisco Bay Area price levels with allowances to provide for future inflation. Included are all costs necessary for the design and construction of the described system, ready for operation, with the exception of rolling stock, financing charges, and District administrative expenses. The construction costs of the system and the Trans-Bay Tube are summarized in the accompanying tables.

METHODS OF ESTIMATING. The estimate has been accurately developed to a degree of detail commensurate with the thoroughness of route location and completeness of design information available.

Typical designs were prepared for each feature of the work in sufficient detail so that accurate determination of the quantities of materials could be made. Construction quantities for each route and segment were computed by applying the appropriate typical designs to the specific conditions of line and grade indicated on the plan and profile sheets.

Recent average low-bid prices for comparable work in the San Francisco Bay Area were applied to these quantities to derive the cost. Where data for similar work were lacking, labor and material costs were developed on the basis of local construction practices and checked against local quotations where possible.

Construction methods and procedures utilized on similar work in this and other areas were studied carefully. Locally, for example, the Webster Street (Oakland) tube construction and several tunnel projects were evaluated. Reference was made to recent extensions of the Toronto and New York subway systems and to construction of the Hampton Roads (Virginia) and Patapsco River (Maryland) vehicular tubes.

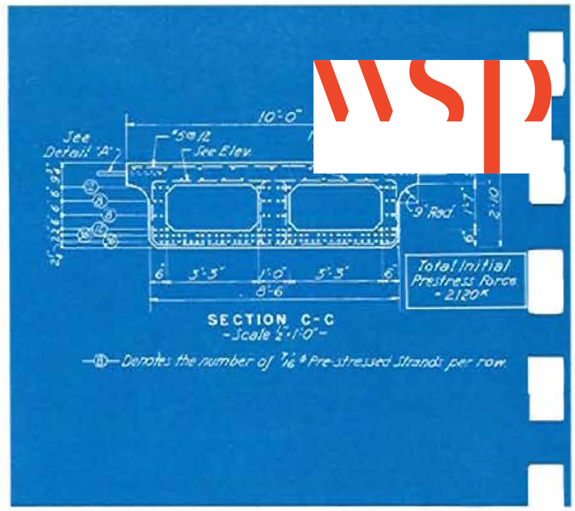
The construction methods and cost estimates for major portions of the work were reviewed with recognized consultants.

SIGNIFICANT PHYSICAL FACTORS. In selecting construction methods and establishing prices, considerable study was made of geological conditions in areas to be traversed. Special emphasis was placed on determination of rock quality and the extent and location of earth faults in the vicinity of the tunnels; on subsidence problems, on ground water, and on soil conditions to be encountered in the subways; on the materials comprising the Bay bottom along the route of the tube; and on soil bearing values and slope stability throughout the system. Investigation was accomplished through actual field inspection by engineering geologists, supplemented by review of geological maps, engineering reports, and past experience, as well as by core borings in the bottom of the Bay.

The estimated costs associated with the need for underpinning of adjacent structures during the construction period were established by enlisting the cooperation of local engineers and architects in furnishing foundation plans of typical important existing structures along the subway routes. Representative designs for underpinning were made, quantities computed, and costs evaluated for local conditions.

Maintenance of both rail and vehicular traffic during the construction period was carefully considered, and allowances are included in the estimate to detour traffic around the work and to provide temporary decking for resumption of normal street traffic over the excavations while work is in progress. Traffic maintenance is particularly expensive in downtown subway construction and in portions of the system in or adjacent to existing railway and freeway rights of way.

In order to develop the costs for utility relocation, the respective utility organizations were consulted to determine the extent of interference that might be anticipated. A preliminary scheme for relocation or maintenance of the utility was developed in collaboration with the agency concerned. In some cases estimates were



developed for this work by the controlling agency, while others were individually developed based on estimated quantities and unit prices.

The estimated costs of acquisition of necessary rights of way were established by local specialists experienced in the appraisal of property and familiar with local trends of real estate values. The costs of right of way for both underground and aerial construction were established based on current practices of the California Division of Highways.

The estimate includes the cost of twenty-three grade-separation structures carrying local traffic over or under the Southern Pacific Coastal Division tracks and the rapid transit Peninsula Line. The present basis generally provides for participation by the state to the extent of approximately 45% and by the railroad to the extent of approximately 10% of costs. With such arrangements, local participation is approximately 45% or less. In these estimates, it is assumed that the San Francisco Bay Area Rapid Transit District would pay the local share only, and the estimates are credited with 55% participation by others in the grade-separation costs. To implement the program, however, it is emphasized that the state will have to appropriate adequate funds for its share.

Allowance for Future Inflation in Construction Costs. The construction estimate reflects wage rates and material prices in effect in the San Francisco Bay Area at the end of the first quarter of 1960, the date when the basic estimates were prepared. Careful review of cost trends in heavy construction in California and nationwide during the decade 1950-1960 indicates that inflation has substantially increased construction costs over the years. Allowance to compensate for a probable continuing inflationary trend during the construction period required for this project was considered a necessary part of the estimate.

Historical cost trends for each of the major categories of work were considered separately and projected forward in accord with a proposed construction schedule. A cost curve for each was established, based on one or more of fifteen different regularly published indices extending back to 1950 and extrapolated through 1966. Normal construction progress was assumed for each category of work within the established time schedule for the project, and the amounts of inflation for each category were computed. The total computed amount of inflation was then distributed uniformly among the various routes and segments, as each is composed of several categories of work.

By 1966 approximately two-thirds of the construction cost will have been expended. Derivation of the approximately 204-million-dollar amount allocated to inflation is based on projection of cost trends to the end of 1966 and the continuation of that level of inflation to the end of the project. This represents a proper allowance for future inflation and is consistent with other estimates of economic growth within the area and the probable effect of technological developments.

Definition of Construction Cost Items. The cost of the rapid transit system, including the Trans-Bay Tube and its approaches, is divided into the cost items in the summary tables. The elements included in each item are as follows:

Track and Structures. Costs to construct the transit structures between stations, including all related costs, such as track work, site preparation, street widening and restoration, fencing, traffic maintenance during the construction period, grade separation structures, and protection of existing buildings.

Stations. Costs of all station construction as well as the track structure within the station, the parking and access area construction, and the fare collection system. Related costs are identical with those listed above under "Track and Structures."

Yards and Shops. Costs for transit yard facilities; service, inspection, and routine maintenance buildings and equipment; track work within the yard limits and lead tracks; and other components incident to the storage, maintenance and repair of transit rolling stock and equipment. The cost of the central administration building is included in this item.

Electrification. Costs of the electrical system to furnish power for train propulsion and control, including such items as utility connections, substations, the third rail for train power, and incidental electrical facilities.

Train Control. All costs of the automatic train control system.

Utility Relocation. All costs incidental to the relocation and maintenance of utility installations necessitated by construction of the transit system. Electric power distribution, communication, gas, water, steam, sewage and storm drainage are affected.

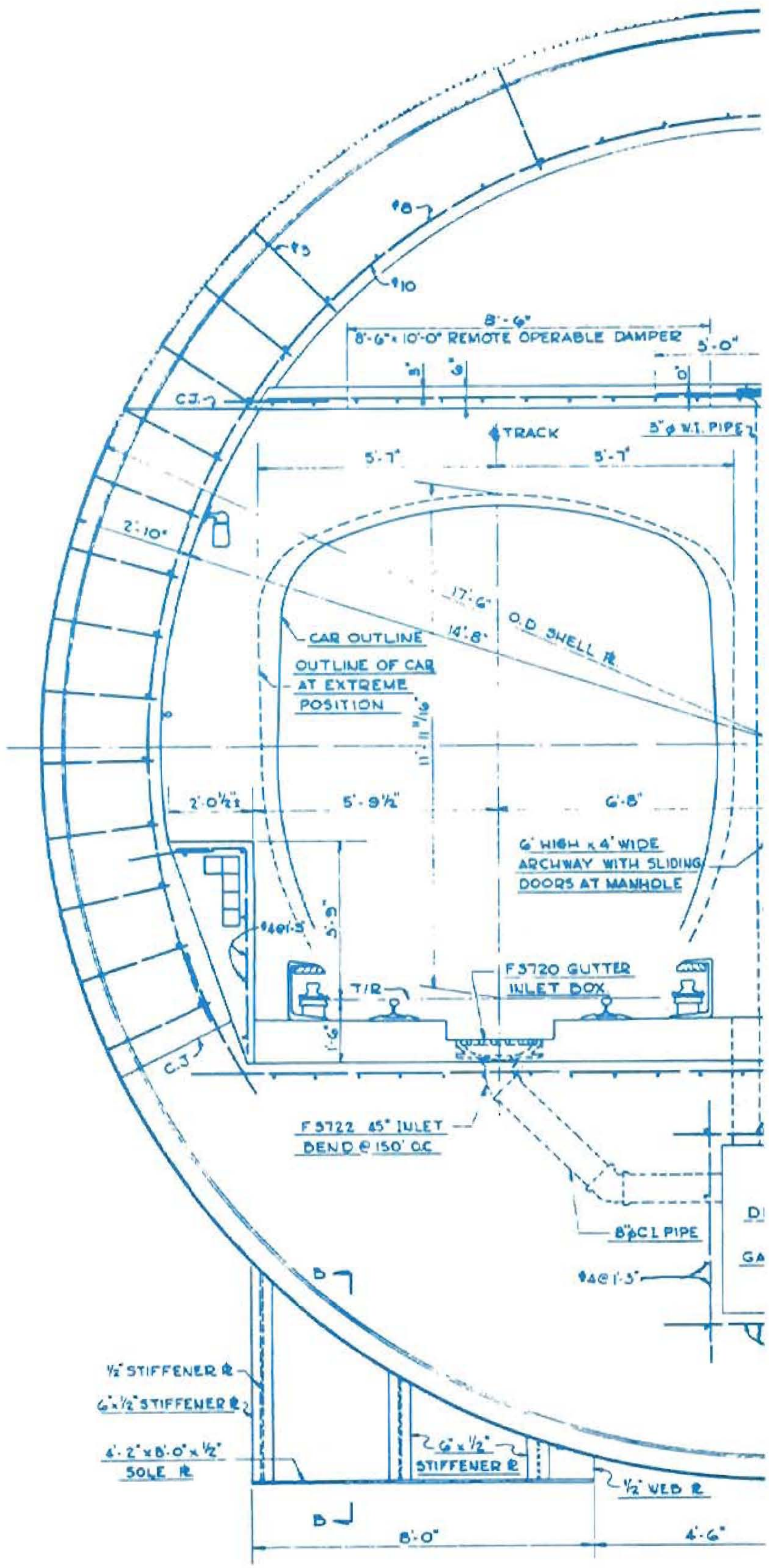
Engineering and Charges. These costs include fees for architectural and engineering services as well as construction management costs during the construction period. Interest during construction, operating capital, financing charges, and District administration expenses are not included.

Right of Way. All costs relative to the acquisition of property required for the construction of the transit system as well as for the demolition of existing improvements, the cost of title investigations, appraisals and negotiating and legal expenses incident to the right of way acquisition.

Contingencies. A contingency is included amounting to 10% of the sum of all construction costs including engineering and charges and right of way.

Inflation. This cost is an allowance to cover anticipated increases in construction costs over the first quarter 1960 price levels used in preparing the estimate.

Pre-Operating Expenses. Before formal revenue operation can begin over any completed segment of the rapid transit system, it will be necessary to plan operations, recruit and train personnel, and perform other preparatory functions. These pre-operating expenses are in addition to the capital cost of construction of the system, and they are estimated at a cost of $7,000,000. The total of the capital cost of construction and the pre-operating expense is $1,077,207,000, and it is this amount that must be provided from the issuance of general obligation bonds by the District.



SUMMARY OF ESTIMATED CONSTRU

Lines	Track & Structures	Stations	Yards & Shops	Electrification
CONSTRUCTION COST				
West Bay Routes				
San Francisco Downtown	$ 46,473,000	$ 35,719,000	—	$ 1,983,000
Peninsula Line	71,563,000	16,487,000	$ 4,901,000	22,789,000
Marin Line	82,438,000	19,607,000	1,772,000	13,217,000
East Bay Routes				
Oakland Downtown	26,729,000	15,677,000	—	1,633,000
Berkeley-Richmond Line	32,947,000	13,989,000	1,478,000	8,583,000
Central Contra Costa Line	68,170,000	10,696,000	958,000	12,201,000
Southern Alameda County Line	42,114,000	11,590,000	1,504,000	15,270,000
Central Yard & Shops and Administration Building	—	—	6,861,000	809,000
SUB TOTAL	$370,434,000	$123,765,000	$ 17,474,000	$ 76,485,000
Credit for Participation by Others				
NET CONSTRUCTION COST				
PRE-OPERATING EXPENSE				
TOTAL COST TO DISTRICT				

TRANS-BAY LINE

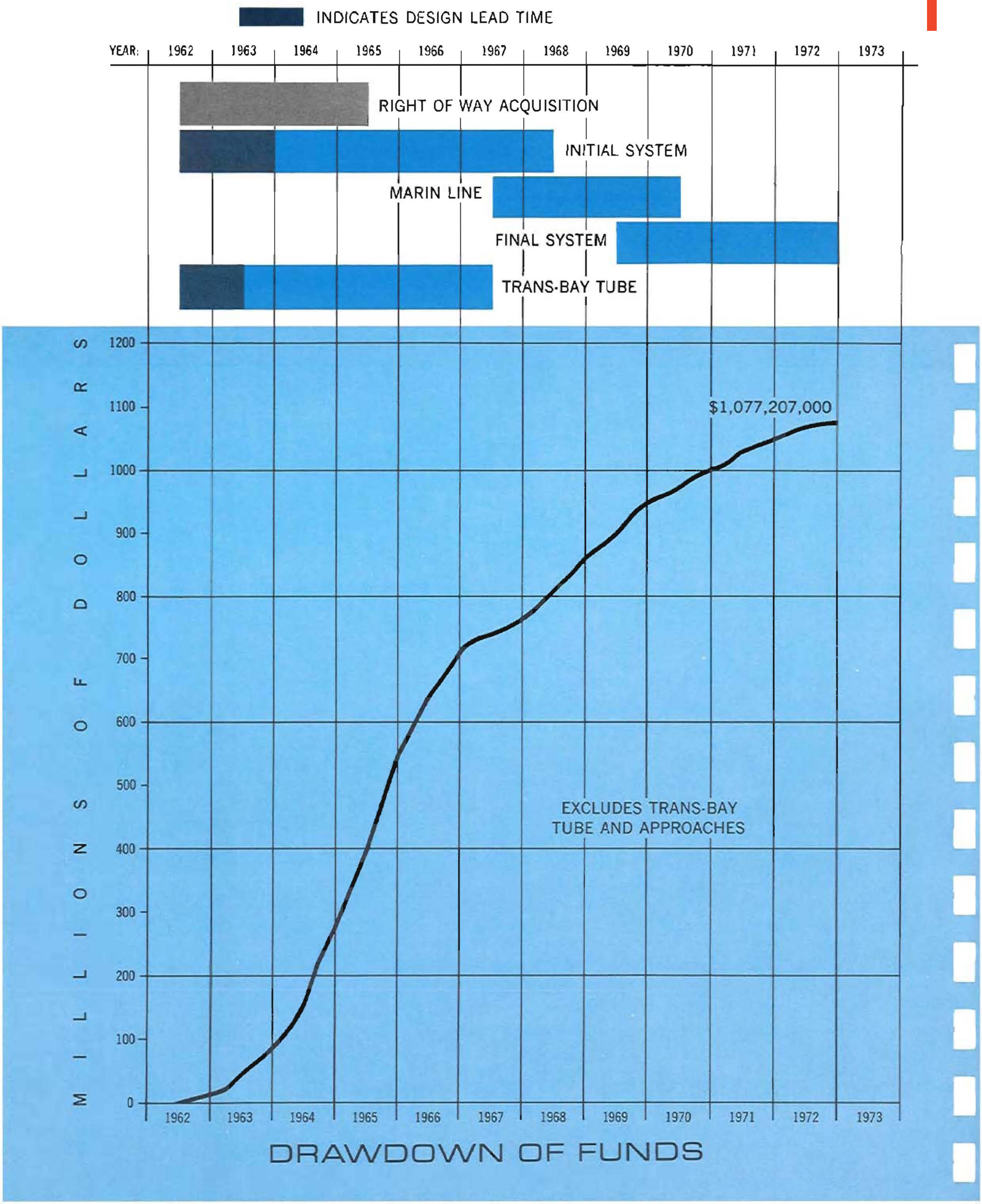
Lines	Track & Structures	Stations	Yards & Shops	Electrification
TRANS-BAY LINE				
San Francisco Approach	$ 16,996,000	—	—	$ 845,000
Subaqueous Tube	57,284,000	—	—	4,087,000
Oakland Approach	6,787,000	—	—	1,016,000
TOTAL COST	$ 81,067,000	—	—	$ 5,948,000

COST & PRE-OPERATING EXPENSE

Train Control	Utility Relocation	Engineering & Charges	Right-of-Way	Contingencies	Inflation	Total
$ 496,000	$ 12,427,000	$ 9,710,000	$ 2,994,000	$ 10,980,000	$ 24,156,000	$ 144,938,000
5,268,000	14,134,000	13,513,000	28,018,000	17,667,000	38,869,000	233,209,000
3,188,000	2,517,000	12,274,000	7,666,000	14,268,000	31,389,000	188,336,000
610,000	6,549,000	5,120,000	12,585,000	6,890,000	15,158,000	90,951,000
2,286,000	2,727,000	6,201,000	27,365,000	9,558,000	21,028,000	126,162,000
3,146,000	2,075,000	9,724,000	10,220,000	11,719,000	25,781,000	154,690,000
3,620,000	2,712,000	7,681,000	13,739,000	9,823,000	21,610,000	129,663,000
5,817,000	—	1,348,000	2,464,000	1,730,000	3,806,000	22,835,000
$ 24,431,000	$ 43,141,000	$ 65,571,000	$105,051,000	$ 82,635,000	$181,797,000	$1,090,784,000
						20,577,000
						$1,070,207,000
						7,000,000
						$1,077,207,000

Train Control	Utility Relocation	Engineering & Charges	Right-of-Way	Contingencies	Inflation	Total
$ 76,000	$ 720,000	$ 1,863,000	—	$ 2,050,000	$ 4,510,000	$ 27,060,000
564,000	1,470,000	6,341,000	$ 47,000	6,979,000	15,354,000	92,126,000
259,000	370,000	843,000	977,000	1,026,000	2,256,000	13,534,000
$ 899,000	$ 2,560,000	$ 9,047,000	$ 1,024,000	$ 10,055,000	$ 22,120,000	$ 132,720,000

CONSTRUCTION SCHEDULE



DRAWDOWN OF FUNDS

CONSTRUCTION SCHEDULE AND DRAWDOWN OF FUNDS

Construction of 120 miles of rapid transit facilities in a metropolitan area is a task of major dimension requiring careful scheduling and years of continuous construction. Among the important factors governing the schedule are the capacity of the construction industry to assimilate the work, the opening to service of partial segments, and the ability of the District to provide funds and to acquire the necessary right of way. A schedule in balance with these factors is required not only to assure early beginning of service, but also to avoid imposing unnecessarily high costs.

Construction periods required vary considerably for different types of construction and for different topographic conditions. Among the difficult or time-consuming elements in this system are the long Berkeley Hills and Sausalito tunnels, the Trans-Bay Tube, and the subway complexes in the major central business districts. Proper scheduling for all components is essential to continuous, efficient and economic construction.

The construction schedule establishes the rate at which funds are needed. Commitment and use of money at all times must be within the ability of the District to borrow funds. The District's financial consultants have provided an estimate of future bonding capacity designed to give the District strong assurance of its ability to finance work within these estimated limits.

Recognizing these major factors, a construction schedule of ten and one-half years was established. Engineering design and right-of-way acquisition are scheduled to start on July 1, 1962. Construction is scheduled to start on January 1, 1964, with the final increment of construction to be completed by December 31, 1972. Right-of-way acquisition will be accomplished as early as possible to insure availability and to take advantage of lower costs.

The essential aspects of the schedule are depicted graphically on the accompanying chart. The schedule contains three dates of major significance.

a. By July 1, 1968, over half of the system will be completed and open to traffic. This partial system will provide service in the East Bay between the Oakland central business district and Richmond, Orinda, and Hayward. It will also include the Trans-Bay connection between Oakland and San Francisco and Peninsula service from San Francisco to Palo Alto.

b. By July 1, 1970, service from the center of San Francisco across the Golden Gate Bridge to Corte Madera will be added.

c. By December 31, 1972, the balance of the system will be completed. Service in central Contra Costa County will be extended to Concord and in Alameda County to Fremont. In Marin County, service to Santa Venetia will be opened.

Within this schedule as various useable segments of the system are completed, they will be opened to service. One segment of route must be available early for use in testing the equipment and control system and for training personnel.

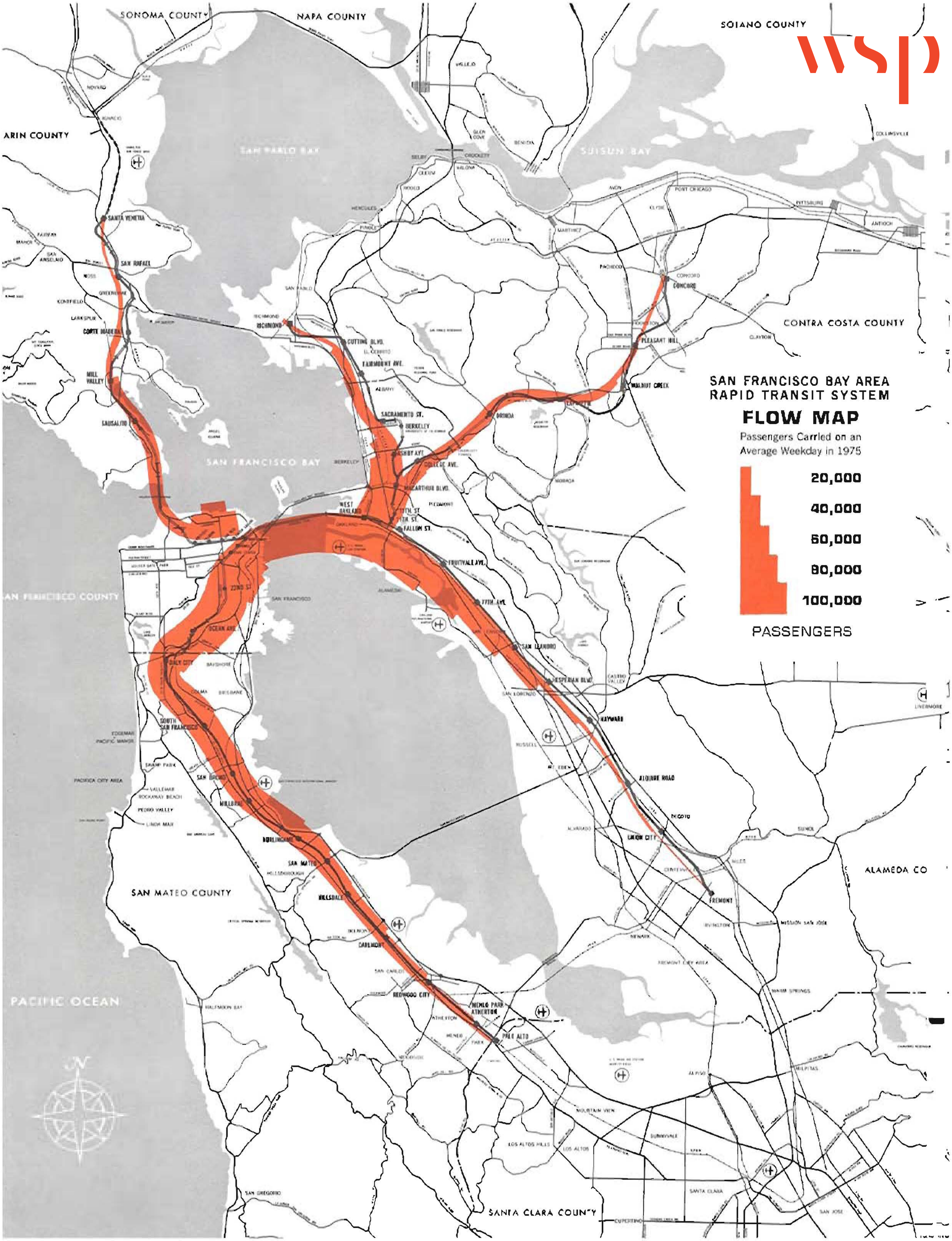
The subaqueous Trans-Bay Tube forms the essential link between the east-bay and west-bay portions of the system. Although it is to be financed and built by the California Toll Bridge Authority, the construction of the tube and the remainder of the system must be closely coordinated. Engineering design on the tube should begin concurrently with that for the initial parts of the rapid transit system. Actual construction requires four years and should be completed by July 1, 1967.

Relating the estimated capital cost of the system, including the pre-operating expenses, with the construction schedule and applying a reasonable rate of expenditure for each of the components, the drawdown of funds was established. A summation of these dollar requirements for each construction element provides the overall drawdown-of-funds curve for the system, less the Trans-Bay Tube and its approaches, shown in the drawdown graph.

Included in the Appendix are detailed tabulations of the estimated drawdown of funds. In these tables the Trans-Bay Tube and its approaches are tabulated separately, since the tube and its approaches are legally subject to different financial arrangements.


CURB LANE

PATRONAGE & OPERATIONS


SAN FRANCISCO BAY AREA
RAPID TRANSIT SYSTEM
FLOW MAP
Passengers Carried on an Average Weekday in 1975
20,000
40,000
60,000
80,000
100,000
PASSENGERS
SONOMA COUNTY
NAPA COUNTY
SOLANO COUNTY
CONTRA COSTA COUNTY
ALAMEDA CO
SAN MATEO COUNTY
SANTA CLARA COUNTY
PACIFIC OCEAN
SAN PABLO BAY
SUISUN BAY
SAN FRANCISCO BAY

PATRONAGE

Estimates of patronage are the basis for a forecast of rapid transit revenue, operating expense, and requirements for rolling stock. The forecast of traffic volumes which will be attracted to the proposed rapid transit system is a key element in economic studies of the system. In addition, detailed patronage estimates define some of the parameters in physical features and service to be provided, thus serving as a control against excess or deficiency in design.

Estimates of transit patronage must be based on a comprehensive understanding of the travel volumes and patterns within the area of interest to the system. This entails a knowledge of the historical development and underlying influences affecting traffic growth and change. An extensive documentation of past and present Bay Area travel characteristics was therefore the foundation for patronage studies.

BAY AREA TRAFFIC STUDIES. The origin-destination survey is the tool for measuring traffic volumes and patterns. As used in the rapid transit studies, this involved division of the Bay Area into a number of logically defined traffic zones and the measurement of traffic volumes within, among and through these zones by origin, destination, time of day, mode of travel, and purpose of trip. The principal survey available for use in the current rapid transit study was conducted throughout the Bay region in 1954 for the San Francisco Bay Area Rapid Transit Commission. This study did not include data relating to internal movements in urban East Bay or in San Francisco. The latter movements, however, were the subject of the Bay Area Metropolitan Traffic Survey conducted by federal, state, and local highway agencies in 1946-1947.

Both of the above studies were updated to the 1959 level in terms of annual average weekday traffic. The 1954 survey was updated by means of transit and auto growth factors developed from actual changes in traffic volumes, as measured at nine cordon lines strategically placed so as to intercept all major highway and transit movements of significance in rapid transit planning.

The internal auto person-trips in the 1946-1947 survey were updated by means of analysis which measured changes in motor vehicle registration within each traffic zone as well as changes in motor vehicle usage and average auto occupancy. Zones of heavy retail and industrial concentration were specially treated. Internal transit person-trip volumes were updated by analysis of the traffic records for individual transit routes. From these data, final internal traffic volumes between zones were obtained.

Both regional and internal traffic volumes between zones, estimated at the 1959 level, were tested against valid 1959 motor vehicle and transit screenline field counts and independent origin-destination surveys made by others. The results of these tests indicate that the estimated zone-to-zone volumes are within acceptable margins.

TRAFFIC PROJECTION. Once accurate travel movement of people for 1959 was determined, it was necessary to predict future volumes and patterns. The year 1975 was selected as a time base for forecasting Bay Area traffic movements between regional cordon areas. Two separate methods were used in obtaining the final projection factors for rapid transit traffic. The first method utilized a special analysis to provide a measurement of the attraction and the generation of trips between areas, considering pertinent factors such as jobs, residential population, auto registration, and travel time. This step yielded separate predictions of commute trips and those trips made for other purposes on an annual average weekday in 1975.

The second method used to forecast 1975 traffic was a projection of 1959-level data by means of a comprehensive series of factors derived primarily from the statistical extrapolation of present trends. The two analyses were conjoined and used to develop the final projection factors employed for forecasting rapid transit traffic.

DIVERSION RESEARCH. The many unique features of the proposed San Francisco Bay Area rapid transit system, such as its high speed, frequent service, long average length of trip, and regional character, indicated the necessity for careful study of the numerous factors influencing traffic distribution between highway and transit facilities. Comparatively little research based on observed data was available at the outset of this study to aid in estimating how total traffic between survey zones could be expected to distribute itself between such facilities.

For this project an extensive investigation was made of the factors influencing traffic distribution by mode of travel, making use of the extensive origin-destination, population, vehicle registration, personal income, travel time, cost, distance, and other data available in the project area. Study was concentrated, among other sources, on available field data from the 1954 origin-destination survey, principally in the traffic corridor along the Peninsula between San Francisco and San Jose. There, relatively high volumes of interurban passenger traffic were reasonably served by traditional standards by a balanced combination of the Southern Pacific rail commute line, Greyhound bus routes, the Bayshore Freeway, and other highway facilities. The corridor is confined on the east by the Bay and on the west by the spine of hills extending down the Peninsula.

Analysis of the extensive data available within this corridor identified and permitted evaluation of several factors of significance in estimating rapid transit utilization. Of principal importance were whether the travel occurs during peak periods in the peak direction, whether the trip is between home and work or for some other purpose, and whether the trip is to or from a major business district. For each category of potential rapid transit trip, the ratio of door-to-door travel time by rapid transit to door-to-door travel time by automobile was determined to be the best measurement of propensity to use rapid transit. Special statistical analysis was extensively employed in developing final graphic diversion curves from the field data.

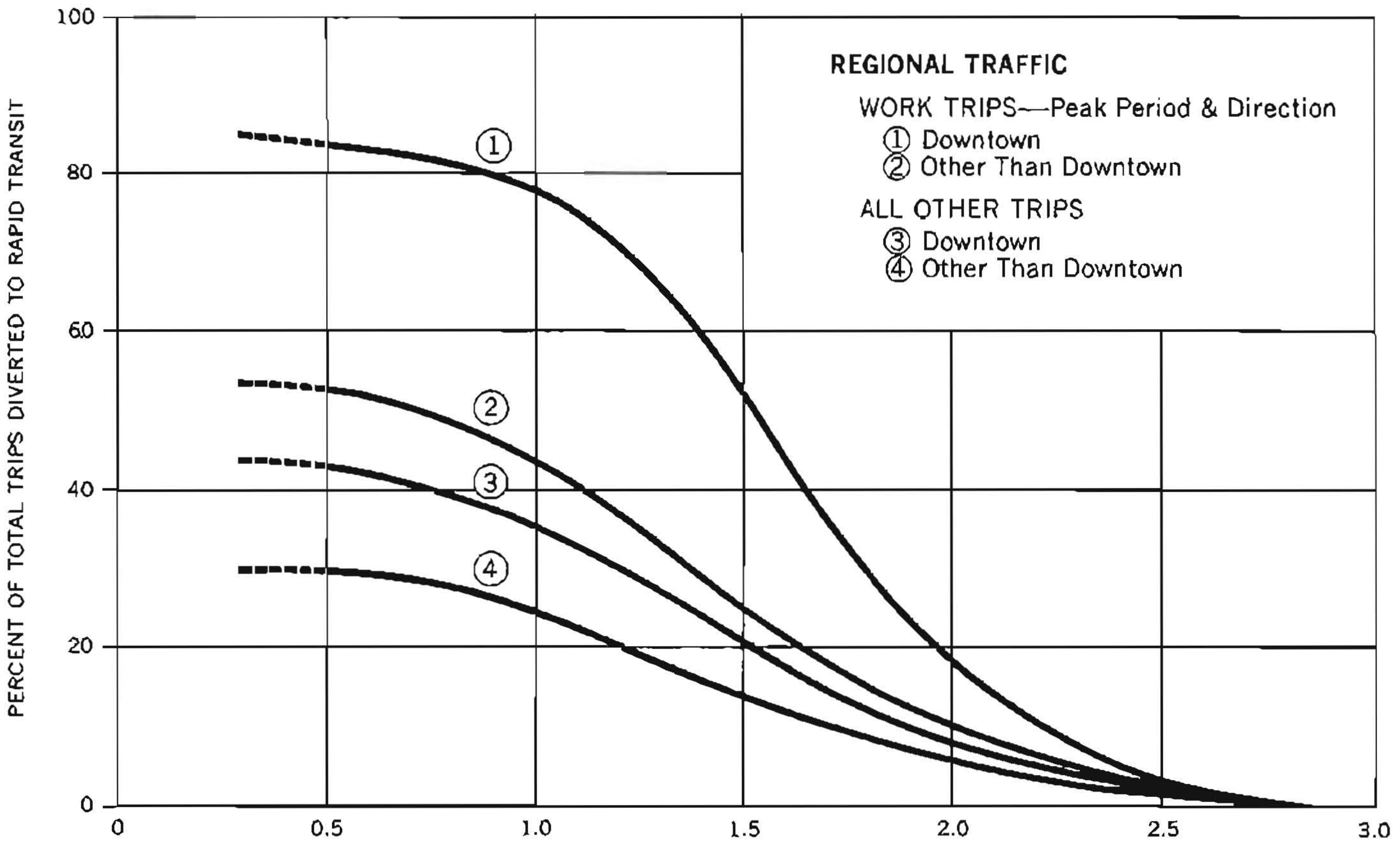
Independent tests, using available traffic data for other regional corridors in the Bay Area and for local East Bay movements to Oakland, were employed as one of several steps in the development of the diversion curves. Other steps included close study of and comparison with diversion curves developed in other projects. With limited exceptions, however, the latter were developed without the support of comprehensive field data and subsequent mathematical analysis.

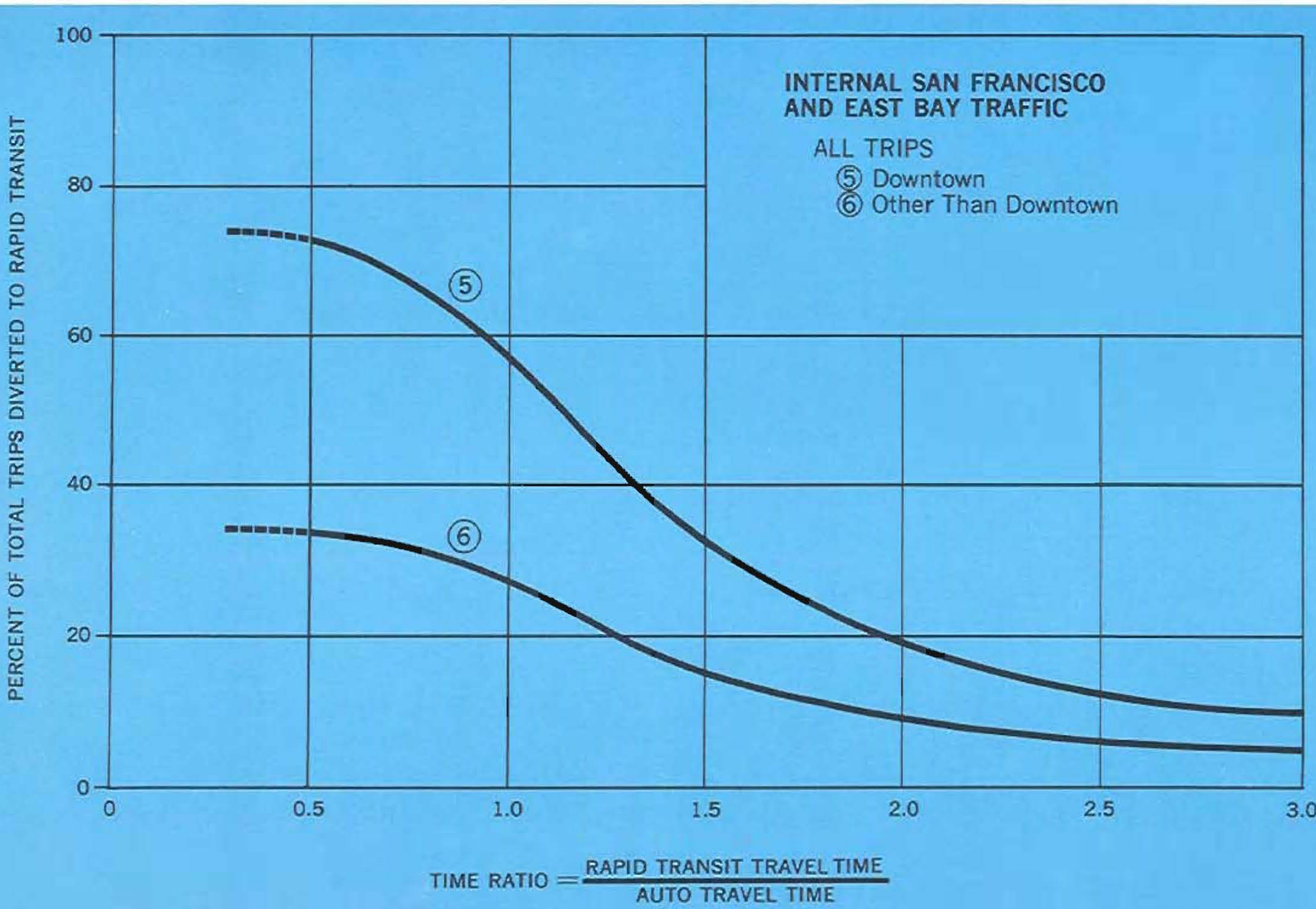
As a result of the above investigations and after extensive finalizing steps, it was possible to develop the series of time-ratio diversion curves shown on the accompanying graphs. Four curves were developed for regional traffic of potential interest to rapid transit as shown on the upper graph. One curve is for peak-period, peak-direction work trips having one or both trip terminals in downtown San Francisco or Oakland. The second curve is for peak-period, peak-direction work trips having neither trip terminal in downtown San Francisco or Oakland. The third and fourth curves are for all other trips, respectively, with and without trip terminals in downtown San Francisco or Oakland. For internal San Francisco and internal East Bay traffic, which in the Bay Area Metropolitan Traffic Survey was not segregated according to trip purpose or time of day, two additional time-ratio curves, differentiating only between downtown and non-downtown trips, were developed and are portrayed on the lower graph.

The charts show, for example, that if the travel time is the same by rapid transit and by auto (time ratio of 1.0), the percent of total trips diverted to rapid transit would be about 77 per cent for peak-period, peak-direction work trips to and from a major central business district (Curve No. 1, Regional Traffic), and it would be about 45 per cent for such trips neither going to nor coming from a major central business district (Curve No. 2, Regional Traffic).

Rapid Transit Patronage. Once route selection studies had determined the location of rapid transit lines and stations, it was possible to define those trips of interest to rapid transit. These are trips of sufficient length and with origins and destinations in suitable proximity and geographic orientation to rapid transit lines so as to be susceptible of diversion to rapid transit. In this way, trips clearly unable to make effective use

RAPID TRANSIT DIVERSION CURVES





of rapid transit were eliminated from further consideration in the analysis.

For those traffic volumes remaining, door-to-door peak and off-peak travel times for each trip by rapid transit and by automobile were calculated, using the expanded network of freeways, arterials, and local streets assumed to be available during the years for which patronage estimates were to be prepared. Ratios of travel time via rapid transit to travel time by automobile were then computed, and by application of the final diversion curves heretofore described, rapid transit passenger volumes were estimated.

With respect to patronage estimates for intra-San Francisco trips an adjustment was made to allow for the effect of the higher cost of a combined streetcar-rapid transit trip or bus-rapid transit trip, compared to the cost for a streetcar or bus trip today. A similar adjustment was made for trips among the East Bay cities from Richmond to Hayward, inclusive.

Because construction plans call for opening of the system in several consecutive stages primarily from 1968 to 1972, patronage for each successive rapid transit route configuration was estimated. These estimates take into account the maturing period following the opening of each new portion of the system.

The accompanying flow map at the beginning of this section depicts the resulting rapid transit traffic for an average weekday in 1975. Annual patronage estimates for the years of the forecast, 1968 through 1980, are presented in the accompanying tabulation.

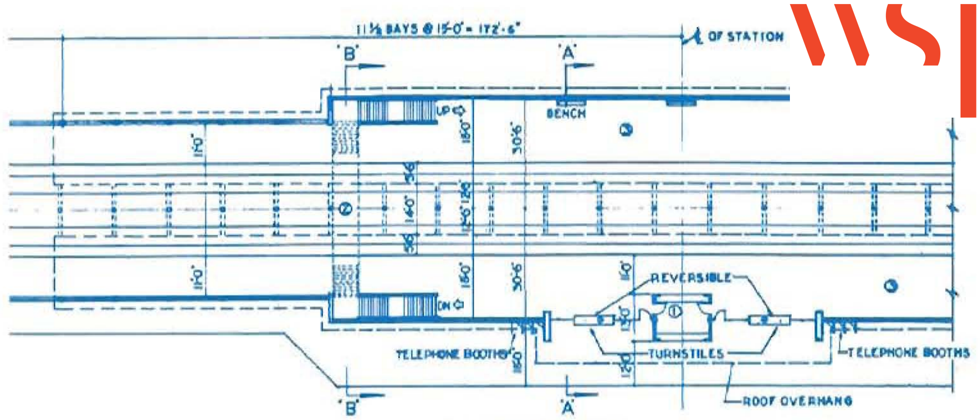
Fiscal Year Beginning July 1	*Total Passenger Trips (One-way trips between two points)*
1968	76,755,000
1969	84,208,000
1970	103,484,000
1971	110,989,000
1972	115,580,000
1973	118,326,000
1974	120,394,000
1975	121,994,000
1976	123,218,000
1977	124,296,000
1978	125,371,000
1979	126,417,000
1980	127,470,000

General Assumptions. The estimates of patronage just presented and those of revenue, operating expense, and requirements for rolling stock, which are described in the following pages, are based upon certain general assumptions as follows:

1. The same general trends of economic activity and business conditions experienced during the past five years in the Bay Area will continue throughout the period of the estimate.
2. Adequate access and parking areas will be provided for patrons at rapid transit stations. These facilities are included in this plan and in the estimates of construction cost.
3. Other transit service in the Bay Area will be coordinated with regional rapid transit in order to secure re-routing, where feasible, of existing interurban and local transit operations to act as feeders to the regional rapid transit system.
4. The San Francisco Bay Area Rapid Transit District will retain the powers delegated to it by existing law to establish fares, concession rates and fees.
5. There will be no adverse legislation affecting the use, operation, condition, or financial obligations of the San Francisco Bay Area Rapid Transit District or the rapid transit system.
6. The rates of toll charged for vehicular passage across San Francisco Bay and the Golden Gate will not be reduced to an extent that will significantly

■ TYPICAL FARES BETWEEN SELECTED STATIONS

	PALO ALTO	REDWOOD CITY	SAN MATEO	MILLBRAE	DALY CITY	CIVIC CENTER	POWELL STREET	MONTGOMERY STREET KEARNY STREET	11th STREET	19th STREET	ORINDA	WALNUT CREEK	CONCORD	FREMONT	HAYWARD	SAN LEANDRO	FRUITVALE AVENUE	BERKELEY	FAIRMONT AVENUE	RICHMOND	SANTA VENETIA	SAN RAFAEL	SAUSALITO	FILLMORE STREET
REDWOOD CITY	$0.25																							
SAN MATEO	0.35	$0.25																						
MILLBRAE	0.45	0.40	$0.25																					
DALY CITY	0.60	0.55	0.40	$0.25																				
CIVIC CENTER	0.70	0.65	0.50	0.40	$0.25																			
POWELL STREET	0.70	0.65	0.50	0.40	0.25	$0.25																		
MONTGOMERY STREET KEARNY STREET	0.75	0.65	0.50	0.40	0.25	0.25	$0.25																	
11th STREET	1.00	0.90	0.75	0.65	0.55	0.40	0.35	$0.35																
19th STREET	1.00	0.90	0.75	0.65	0.55	0.40	0.35	0.35	$0.25															
ORINDA	1.15	1.05	0.90	0.80	0.70	0.55	0.55	0.55	0.25	$0.25														
WALNUT CREEK	1.25	1.20	1.05	0.95	0.85	0.70	0.70	0.70	0.45	0.45	$0.25													
CONCORD	1.40	1.30	1.15	1.10	0.95	0.85	0.80	0.80	0.55	0.55	0.40	$0.25												
FREMONT	1.40	1.35	1.20	1.10	0.90	0.85	0.85	0.85	0.60	0.60	0.75	0.90	$1.00											
HAYWARD	1.25	1.15	1.00	0.90	0.80	0.65	0.65	0.65	0.40	0.40	0.55	0.70	0.85	$0.30										
SAN LEANDRO	1.15	1.05	0.90	0.80	0.70	0.55	0.55	0.55	0.25	0.30	0.45	0.60	0.70	0.45	$0.25									
FRUITVALE AVENUE	1.05	0.95	0.80	0.70	0.60	0.45	0.45	0.45	0.25	0.25	0.35	0.50	0.65	0.50	0.35	$0.25								
BERKELEY	1.05	1.00	0.85	0.75	0.60	0.50	0.50	0.50	0.25	0.25	0.30	0.45	0.60	0.70	0.50	0.40	$0.25							
FAIRMONT AVENUE	1.15	1.05	0.90	0.80	0.70	0.55	0.55	0.55	0.25	0.25	0.40	0.50	0.65	0.75	0.55	0.45	0.35	$0.25						
RICHMOND	1.25	1.15	1.00	0.90	0.80	0.65	0.65	0.65	0.40	0.40	0.45	0.60	0.75	0.85	0.65	0.55	0.45	0.25	$0.25					
SANTA VENETIA	1.25	1.15	1.00	0.90	0.80	0.65	0.65	0.65	0.90	0.90	1.05	1.20	1.30	1.35	1.15	1.05	0.95	1.00	1.05	$1.15				
SAN RAFAEL	1.20	1.10	0.95	0.85	0.75	0.60	0.60	0.60	0.85	0.85	1.00	1.15	1.25	1.30	1.10	1.00	0.90	0.95	1.00	1.10	$0.25			
SAUSALITO	1.00	0.95	0.80	0.70	0.60	0.45	0.45	0.40	0.70	0.70	0.85	1.00	1.10	1.15	0.95	0.85	0.75	0.80	0.85	0.95	0.35	$0.25		
FILLMORE STREET	0.75	0.70	0.55	0.45	0.30	0.25	0.25	0.25	0.40	0.40	0.60	0.70	0.85	0.85	0.70	0.55	0.50	0.55	0.60	0.65	0.60	0.55	$0.35	
UNION SQUARE	0.75	0.65	0.50	0.40	0.25	0.25	0.25	0.25	0.35	0.40	0.55	0.70	0.80	0.85	0.65	0.55	0.45	0.50	0.55	0.65	0.65	0.60	0.40	$0.25



PLATFORM PLAN

prejudice the relative attraction of rapid transit compared to the private automobile.

7. Highway planning for the Bay Area will be complementary to and not detractive of the functions of the rapid transit system.
8. An appropriate policy of advertising and public education will be followed by the District to encourage rapid transit patronage.

FARE STRUCTURE

A schedule of proposed station-to-station rapid transit fares was developed. Of prime significance is the necessity that rapid transit fare levels be equated to the cost of other travel modes, principally the automobile. If the cost for travel by rapid transit were to be significantly higher than by auto, rapid transit patronage would be discouraged; and if lower, then less than optimum revenue would result.

Accordingly, the analysis entailed a thorough investigation of typical Bay Area auto-travel costs, including only the effects of auto occupancy, bridge tolls, parking fees, and the costs of gasoline, oil, and normal tire wear; which represent out-of-pocket costs. In addition, existing commute and cash transit fares were taken into consideration. In determining comparable rapid transit travel costs, the costs of any necessary increments of feeder travel were included.

As a result of these studies, it was found desirable and feasible to employ a fare structure based on distance travelled, rather than on the usual flat- or zone-fare types of tariff. A specific fare thus results for each station-to-station trip. The rate schedule provides a minimum fare of 25 cents for any trip up to eight miles, with a gradual decline in cost per mile as distance travelled increases, varying between 3.2 cents per mile at eight miles to 2.25 cents per mile for the longest trips. An additional ten cents is added to the fare for trips that involve crossing San Francisco Bay or the Golden Gate. Typical rapid transit station-to-station fares are illustrated in the accompanying table.

REVENUES

Fare revenue was estimated by multplication of the projected rapid transit passenger volumes for each station-to-station movement times the rapid transit fare for that movement.

Investigation of additional potential sources of revenue resulted in an estimate of one per cent of fare revenue as income from advertising and concessions.

Total estimated revenue for the years of forecast 1968 through 1980, is as follows:

Fiscal Year Beginning July 1	*Gross Fare and Concession Revenue*
1968	$26,714,000
1969	29,571,000
1970	35,696,000
1971	39,334,000
1972	41,475,000
1973	42,717,000
1974	43,594,000
1975	44,289,000
1976	44,814,000
1977	45,279,000
1978	45,762,000
1979	46,223,000
1980	46,681,000

OPERATIONS

The proposed route network and the estimates of rapid transit patronage were the bases for estimating daily train operations. Projected patronage volumes and patterns influenced the arrangement of the various interconnections or junctions between lines. Complete junctions are expensive, not only due to the costs for additional track, switches, and related equipment, but especially because of the high construction and right-of-way acquisition costs in the developed areas where lines meet. Another important consideration is the fact that junctions complicate operational patterns and greatly expand the influence that delay of a single train may have on other train movements. In addition, funnelling several routes into a single two-track trunk line leading to downtown areas inevitably means that the number of trains on all these routes combined cannot exceed the capacity of the central trunk.

With these factors in mind, the way in which lines and train service should be interconnected was planned, resulting in a physical track framework within which all major traffic movements between lines are directly accommodated. Trains are not, however, able to travel directly between the Central Contra Costa Line and the Berkeley-Richmond Line. Also, the Marin Line is operated separately from the rest of the system except for a single-track connection to allow cars to reach the main service shops in Oakland.

Reference to the flow map at the beginning of this section discloses the relative concentration of passenger volumes toward the center of the system. In order to make economic and efficient use of trains, provision is made for turning back some trains short of the ends of lines, especially during peak periods.

Patterns of service are expected to vary through the day. The greatest variety of train routings occurs during peak periods and during the daytime hours between morning and evening peaks. At times of lesser traffic density, the best service can be provided by reducing the amount of variation in runs made and operating frequent service over the routes.

The final element of this planning was the preparation of schedules of train operation, which are important because of four principal considerations. First, the results of the train scheduling analysis provided the basis for determining a large part of rapid transit operating expense, including costs of traction power, train attendants, rolling stock maintenance, and other items. Second, scheduling analysis furnished an actual count of rolling stock requirements. Third, the study measured, again by actual count, the car storage space needed at each yard. Finally, it tested the adequacy of track capacities along critical portions of the routes where the density of train service is relatively high.

Using plans of the proposed routes, performance data for the prototype rapid transit car, and the stop-intervals at each station, running times for the entire system were calculated. These are shown on the accompanying table. Working timetables were then constructed taking into account all necessary practical considerations, such as minimum safe headway between trains, time needed for switching in yards, the minimum time required for reversing trains at turnback points, layover time requirements for attendants, and the like.

Train operation schedules were prepared for average weekdays in the years 1966 and 1975. These served as a firm basis for developing train operation data in the interim years.

Analysis of the completed working timetables allowed estimation of daily car-miles and car-hours operated, the maximum number of cars in each yard at any one time, and other data pertinent to operating expense estimates. The number of employees required and their working hours and wages were determined by proforma assignment of personnel.

Operating Expense. In many important aspects affecting the analysis of operating expenses, the proposed Bay Area system differs from existing rapid transit systems. Primary among these different aspects is its true regional character. As an interurban system serving the major San Francisco Bay Area cities and their suburbs, its routes are of extensive length and its stations are widely spaced in comparison with existing systems. Automatically controlled trains, having acceleration rates and maximum running speeds markedly greater than almost all existing rapid transit rolling stock, make possible average schedule speeds considerably higher than on existing rapid transit systems, and actually twice as high as most. The entire system, in its modern, functional, highly automated design, represents a dramatic advance over existing rapid transit concepts.

Estimating operating expense was, therefore, largely a unique undertaking, necessitating detailed evaluation of each element of expense. Experiences on existing systems did not generally provide valid comparisons. The design of the project introduces the most modern and functional improvements, including automatic train operation. Because of the high schedule speeds, car-miles will be generated at a much faster rate than on presently operating systems, and many items of operating expense, including the salaries of train attendants and annual cost of administration, station operations, and maintenance of way and structures, will be distributed over a greater number of car-miles. As a result, operating expense per car-mile will be relatively low in comparison to existing rapid transit systems using cars of similar capacity.

In preparing estimates of operating expense, the Interstate Commerce Commission expense classifications for electric railways were generally followed. Wherever applicable, with the several qualifications discussed in the preceding paragraphs, the experience of existing American rapid transit systems was used as a general guide. Due to the participation of Mr. Donald C. Hyde, General Manager of the Cleveland Transit System, as consultant for this phase of study, the operating expense data from the Cleveland rapid transit system were particularly valuable. Enhancing this value was the fact that, of the existing systems, Cleveland's system is one of the fastest and most modern.

The following general discussion of estimating methods describes separately the procedure used to determine each major category of operating expense.

The estimate for maintenance of way and structure considered experience with comparable existing facilities, as well as local conditions expected in the Bay Area, such as the normal character of construction and the absence of frost conditions in this area. The Trans-Bay Tube and the rapid transit installation across the Golden Gate Bridge were given separate consideration.

PEAK HOUR TRAIN TRAVEL TI

Line and Station	Minutes: Between Stations	Minutes: From First Station
PENINSULA—TRANS-BAY—CENTRAL CONTRA COSTA LINES		
Palo Alto	—	—
Menlo Park-Atherton	2	2
Redwood City	4	6
Carlmont	3	9
Hillsdale	4	13
San Mateo	2	15
Burlingame	2	17
Millbrae	4	21
San Bruno	2	23
South San Francisco	3	26
Daly City	5	31
Ocean Ave. (San Francisco)	2	33
22nd St. (San Francisco)	3	36
Civic Center (San Francisco)	3	39
Powell St. (San Francisco)	1	40
Montgomery St. (San Francisco)	1	41
West Oakland	6	47
11th St. (Oakland)	2	49
19th St. (Oakland)	1	50
MacArthur (Oakland)	2	52
College Ave. (Oakland)	3	55
Orinda	4	59
Lafayette	5	64
Walnut Creek	4	68
Pleasant Hill	3	71
Concord	4	75
MARIN LINE		
Kearny St. (San Francisco)	—	—
Union Square (San Francisco)	1	1
Van Ness Ave. (San Francisco)	1	2
Fillmore St. (San Francisco)	1	3
Presidio Ave. (San Francisco)	2	5
Sausalito	7	12
Mill Valley	4	16
Corte Madera	2	18
San Rafael	4	22
Santa Venetia	3	25
SOUTHERN ALAMEDA COUNTY—BERKELEY-RICHMOND LINES		
Fremont	—	—
Union City	3	3
Alquire Rd. (Hayward)	3	6
Hayward	4	10
Hesperian Blvd. (San Lorenzo)	4	14
San Leandro	3	17
77th Ave. (Oakland)	3	20
Fruitvale Ave. (Oakland)	3	23
Fallon St. (Oakland)	3	26
11th St. (Oakland)	1	27
19th St. (Oakland)	1	28
MacArthur (Oakland)	2	30
Ashby Ave. (Berkeley)	3	33
Berkeley	2	35
Sacramento St. (Berkeley)	2	37
Fairmont Ave. (El Cerrito)	2	39
Cutting Blvd. (El Cerrito)	3	42
Richmond	3	45

The operating expense for maintenance of rolling stock was based upon car-use intensity expected here and experienced at Cleveland, with additional consideration given to differences in control, propulsion, and other train-borne equipment.

Operation of service included the cost of train attendants, station agents, janitors, yard hostlers, train-control and communication-equipment maintenance and operating personnel, crew dispatchers, patrolmen and watchmen, revenue collectors, station utilities and supplies. and the like. Each item was treated by a separate analysis related to known characteristics of the proposed system, with comparisons in some instances to similar cost for the Cleveland rapid transit system.

The largest single category of operating expense included traction and other electric power. This estimate was composed largely of energy and demand charges for traction power, for which the estimate was based on data developed from the train scheduling analysis. Maintenance and operation of the power system, and the cost of power for uses other than train propulsion were also estimated in this category.

Injuries and damages were estimated with some reference to the Cleveland system, and were related to estimated passenger trips, the number of employees, train-miles and car-miles. The estimate for insurance was equated to Cleveland's ratio of insurance cost to capital investment.

Administrative and general expense included all executive, staff, and clerical salaries plus expenses for such items as advertising, office supplies, auto and truck pool, utilities, special services, financial obligations, and miscellaneous items. The cost for each item was estimated separately.

The basic estimates were prepared for the year 1975 and for certain earlier years. For the remaining span of the forecast, a method of projection based on an estimate of annual car-miles operated in each year was developed. This analysis considered the degree to which each item of operating expense could be expected to vary with car-miles.

An additional cost, called pre-operating expense, was included for a limited period preceding the opening of each major system section. Pre-operating expense includes amounts necessary for planning, recruiting, training, and other preparation prior to the opening of revenue service.

For the fiscal years 1966 and 1967, which comprise the first two years of partial operation, and for the period of pre-operating expense which precedes the opening of revenue service, operating expenses will be met with a reasonable margin by gross fare and concession revenues plus the nominal sum which is included in the capital cost estimates for pre-operating expense. During these two early years of operation no net revenue should be anticipated for the purpose of rolling stock debt service.

The total of annual operating expense plus pre-operating expense for the years of the forecast, 1968 through 1980, is shown in the following table:

Fiscal Year Beginning July 1	*Total Operating and Pre-Operating Expense*
1968	$17,213,000
1969	18,371,000
1970	20,781,000
1971	22,306,000
1972	23,275,000
1973	23,824,000
1974	24,212,000
1975	24,518,000
1976	24,768,000
1977	24,986,000
1978	25,196,000
1979	25,406,000
1980	25,640,000

NET REVENUE. Net revenue equals gross fare and concession revenue minus total operating and pre-operating expense. Net revenue for the years 1968 through 1980 is shown below:

Fiscal Year Beginning July 1	*Net Operating Revenue (Gross Fare and Concession Revenue Minus Total Operating and Pre-Operating Expense)*
1968	$ 9,501,000
1969	11,200,000
1970	14,915,000
1971	17,028,000
1972	18,200,000
1973	18,893,000
1974	19,382,000
1975	19,771,000
1976	20,046,000
1977	20,293,000
1978	20,566,000
1979	20,817,000
1980	21,041,000

No inflation is included in the estimates of revenue and operating expense, which are based on first-quarter 1960 price levels. Fares and revenues would be raised sufficiently in inflationary periods to meet rising operating expenses and still provide the proportional margin of net revenue indicated in the estimates.

It is estimated that the net revenue in each fiscal year of the forecast is sufficient to cover debt service on rolling stock with a reasonable margin. Construction costs, however, must be met from other sources.

ROLLING STOCK REQUIREMENTS

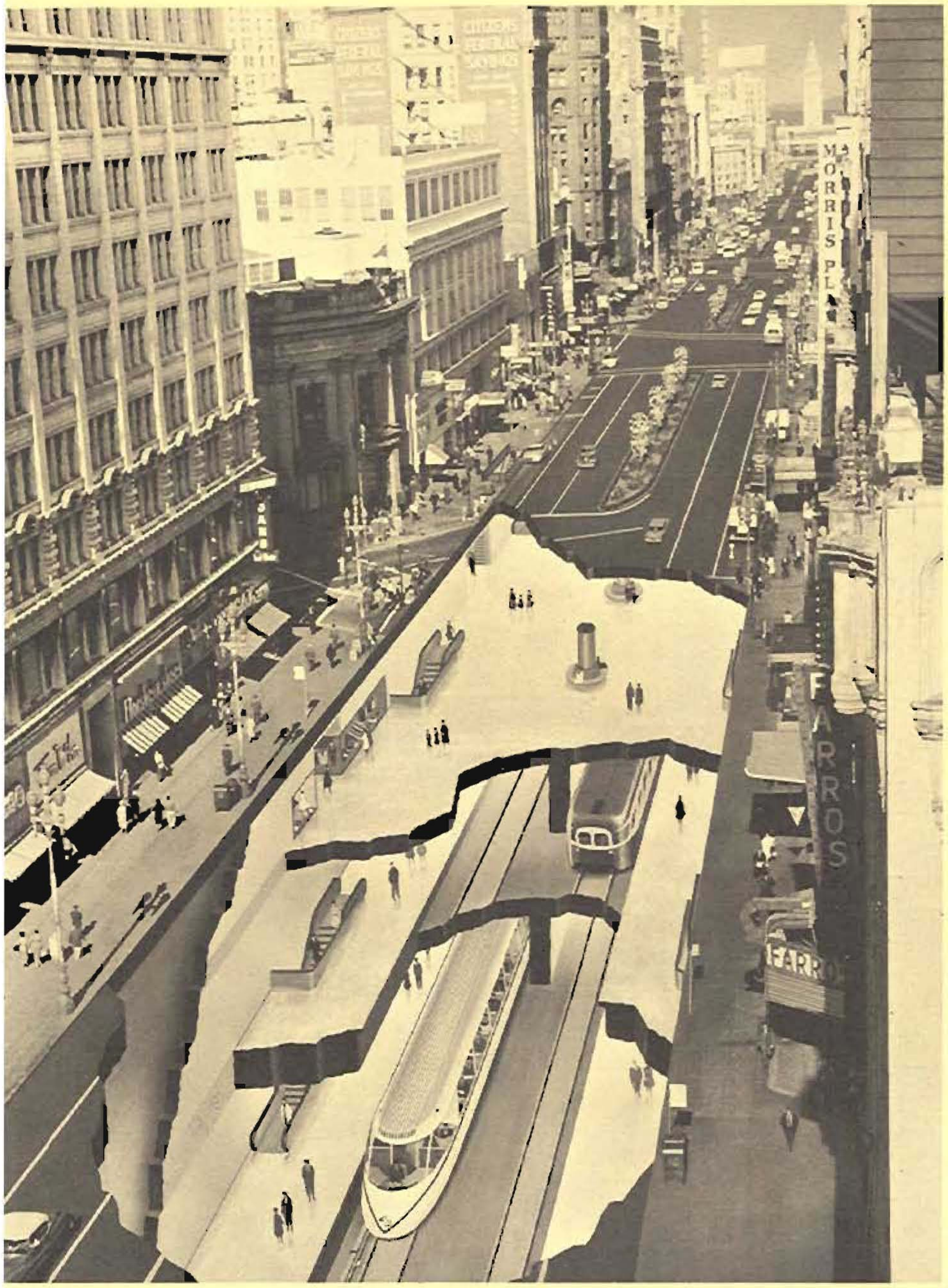
The development of a rapid transit car, as described in an earlier section of this report, included preparation of estimates of car cost. This study included consideration of the possible effects on cost due to financing assumptions, inflation, shipping charges, inspection, and contingencies. The resultant was a total estimated unit cost per car of from $150,000 to $160,000, depending on the date of fabrication.

Based on the results of the train operation analyses for 1966 and 1975, and on the estimated annual car- and passenger-miles for each year of operation, the number of cars required during each year was estimated. During the early years of rapid transit operation, a safety factor was included, so that sufficient cars would be available to provide fully satisfactory service despite the presence of only partially developed patronage levels, as reflected by the annual passenger-mile estimates. A seven per cent allowance for spare equipment has been included in the estimate.

The total number of cars required for each year of operation, 1966 through 1980, and their cumulative cost are tabulated below.

Fiscal Year Beginning July 1	*Cumulative Number of Cars*	*Cumulative Cost*
1966	50	$ 7,500,000
1967	500	77,250,000
1968	590	91,650,000
1969	640	99,650,000
1970	720	112,450,000
1971	800	125,250,000
1972	840	131,650,000
1973	870	136,450,000
1974	880	138,050,000
1975	900	141,250,000
1976	910	142,850,000
1977	920	144,450,000
1978	930	146,050,000
1979	940	147,650,000
1980	950	149,250,000

APPENDIX


MORRIS PL

DRAWDOWN OF FUNDS

Appendix A: Rapid Transit System

(Not including the Trans-Bay Tube and Approaches)

Date Ending	Cumulative Expenditure
7/1/62	0
10/1/62	$ 3,000,000
1/1/63	10,000,000
4/1/63	20,000,000
7/1/63	40,000,000
10/1/63	60,000,000
1/1/64	80,000,000
4/1/64	110,000,000
7/1/64	150,000,000
10/1/64	220,000,000
1/1/65	270,000,000
4/1/65	330,000,000
7/1/65	390,000,000
10/1/65	470,000,000
1/1/66	540,000,000
4/1/66	590,000,000
7/1/66	640,000,000
10/1/66	670,000,000
1/1/67	710,000,000
4/1/67	730,000,000
7/1/67	740,000,000
10/1/67	750,000,000
1/1/68	760,000,000
4/1/68	780,000,000
7/1/68	810,000,000
10/1/68	830,000,000
1/1/69	860,000,000
4/1/69	880,000,000
7/1/69	900,000,000
10/1/69	930,000,000
1/1/70	950,000,000
4/1/70	960,000,000
7/1/70	970,000,000
10/1/70	990,000,000
1/1/71	1,000,000,000
4/1/71	1,010,000,000
7/1/71	1,030,000,000
10/1/71	1,040,000,000
1/1/72	1,050,000,000
4/1/72	1,060,000,000
7/1/72	1,070,000,000
10/1/72	1,075,000,000
1/1/73	1,077,207,000

Appendix B: Trans-Bay Line

(Trans-Bay Tube and Approaches)

Date Ending	Cumulative Expenditure
7/1/62	0
10/1/62	$ 1,000,000
1/1/63	2,000,000
4/1/63	3,000,000
7/1/63	4,000,000
10/1/63	6,000,000
1/1/64	9,000,000
4/1/64	14,000,000
7/1/64	19,000,000
10/1/64	30,000,000
1/1/65	40,000,000
4/1/65	51,000,000
7/1/65	62,000,000
10/1/65	73,000,000
1/1/66	84,000,000
4/1/66	94,000,000
7/1/66	106,000,000
10/1/66	114,000,000
1/1/67	120,000,000
4/1/67	124,000,000
7/1/67	132,720,000

wsp