Inspiring sustainable thinking

Two Projects – Different Eras; Different Tools; Similar Results

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ABSTRACT

Two Projects – Different Eras; Different Tools; Similar Results

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Over the course of the authors career as a Transportation Design Engineer he has had the great privilege of participating in a wide variety of design projects, two of which book-end his career. The first, Whitemud Drive, was designed over a number of years and completed in the late 80’s by a small design team where the author participated as a Geometric Design Engineer. The second, the Highway 63 / Highway 686, Parsons Interchange, was completed in 2013 in a relatively short period of time by a much larger team where he participated as the Project Coordinator.

Whitemud Drive is an urban freeway extending approximately 27 kilometres across the south side of Edmonton from Anthony Henday West to Anthony Henday East. The author was an active participant as the design engineer for the easterly 18.5 kilometres extending from the North Saskatchewan River to Highway 14, now renamed Anthony Henday East. The design components included nine diamond interchanges, two fly-overs, one major stream crossing and one railway grade separation. The Highway 63 / Highway 686, Parsons Interchange is a rural systems interchange that in its ultimate configuration will include approximately 7.5 kilometres of highway, seven bridge structures and a myriad of associated ramps. As Project Coordinator the author was responsible for managing a design team that included in-house designers and several subconsultant specialists.

This paper discusses the processes that were involved then and now in completing the designs of the two projects including the design tools and drafting processes (including tools and techniques); It will look at the methodologies used in the calculation of tender quantities and the preparation of cost estimates and will discuss the advances made in design software; it will compare the end result of the two design processes and lastly it will present the authors opinion on the sacrifices that have resulted from these advances including a lost understanding of the basic geometric functions that are key to geometric design and quantity calculation and the potential loss of the understanding of basic design principles that form the basis of the TAC Geometric Design Manual.

1.0 Introduction

Whitemud Drive is an urban freeway extending approximately 27 kilometres across the south side of Edmonton from Anthony Henday West to Anthony Henday East. The design of the easterly 18.5 kilometres extending from the North Saskatchewan River to Highway 14 was completed over several years starting in 1974 with the design of the section from North Saskatchewan River to 122 Street and continuing east until the design was completed to Highway 14. The design components included nine diamond interchanges, two fly-overs, a major stream crossing over Whitemud Creek at Rainbow Valley and one railway grade separation. The Highway 63 / Highway 686, Parsons Interchange is a systems interchange that in its ultimate configuration will include approximately 7.5 kilometres of highway, seven bridge structures and a myriad of associated ramps. Design on this project commenced in 2011 and after several concept adjustments was tendered for construction in 2013.

The processes that were involved then and now in completing the designs of the two projects including the design tools and drafting processes (including tools and techniques) have evolved significantly as have the methodologies used in the calculation of tender quantities and the preparation of cost estimates. The changes are as a result of the advances made in the software that is used in project design and plan preparation. While the resulting end product has remained the same, there may be a cost in terms of reduced or lost understanding of the basic geometric functions that are key to geometric design and quantity calculation accompanied by a potential loss of the understanding of basic design principles that form the basis of the TAC Geometric Design Manual.

2.0 Design Philosophy

2.1 Basic Approach

The basic approach to the development of project design has not change significantly. The same steps were followed during the design development of Whitemud Drive as were followed in the development of the Parsons Interchange design. These steps include functional plan development, preliminary design and detailed design.

The mechanics involved in the development of these steps has evolved significantly over time but the end result remains the same – namely the production of the set of drawings and specifications that will be used in the tender and construction of the proposed facility.

2.2 Project Drivers

The evolution of the provincial political climate, changing budget demands and outside demands on all resources has resulted in changes to the factors that drive projects and bring them into reality.

Whitemud Drive was an integral part in the implementation of a broader transportation plan that had been developed during a period when growth was occurring at a leisurely rate. As a result the project could easily be staged over a period of time and developed as demand slowly increased and funding became available. The staged approach allowed the design team ample opportunity to review the project parameters prior to proceeding with the design of the next phase. This included a re-evaluation of anticipated capacity requirements, geometric considerations to accommodate those requirements, implementation of measures to improve safety, etc.

The Parsons interchange was a totally reactive project made necessary by the development of a subdivision planned to house an estimated 25,000 people in a short 5 year development period. This short period of time condensed both the planning and design stages which in turn limited the opportunity to study or plan options or to implement a cost effective phased approach to construction. In the end budget limitations forced project staging both for the interchange and the interchange.

3.0 Design Standards

3.1 Geometric Standards

The design standards used for Whitemud drive were based on the Canadian Good Roads Association (CGRA) “Manual of Geometric Design Standards for Canadian Roads and Streets 1963”, the Department of Highways and Transport Province of Alberta “Urban Highway Design Guide (1970)”, ASHTO and a bit later in the project the first TAC “Geometric Design Guide”. The Parsons Interchange project was based on the Alberta Transportation “Highway Geometric Design Guide, 1999” which adapts the TAC Geometric Design Guide to address conditions specific to Alberta.

A comparison between the basic standards set out in the Urban Design Guide and the latest version of the Geometric Design Guide revealed that the basic design principals have changed little over the last 40 years. What has changed is the design philosophy. Early manuals were written in a prescriptive manner offering little choice. Later editions of the TAC Manual, the 1999 version as an example, were written in a manner that offered a design domain allowing the designer the ability to customize the design to suit local conditions and restraints while providing assurance that design standards were met. One example is in the determination of superelevaion. The Urban Highway Design

Guide only offered a table for an e-max of 0.08 where-as the later versions included tables for an e-max of 0.04, 0.06 and 0.08 which provided designers more design flexibility while at the same time placing a greater onus on the designer to be aware of project constraints.

Early versions were limited in the areas that were covered and appeared to be focused on freeways and arterials where-as later versions addressed standards for all roadways based on road classification, traffic volumes and design speed. Coverage in general was expanded from one paragraph for shoulders or medians to an entire section dedicated to each. Sections were added to address design specifics such as lane balance and continuity.

Design considerations for road side safety features such as guardrails, climbing lanes, escape lanes, etc., were added. The information provided included warrants for the determination of the need as well as the criteria needed to define the location and extent of the feature.

As shown in the following table the differences are minor and mostly restricted to expanded areas of application and refinements in definition rather than in revisions to the geometric standards.

Table 1: Design Standards Comparison

Design Criteria	Urban Highway Design Guide (1970)	Geometric Design for Canadian Roads (TAC - 1999)
superelevation	table is for e max 0.08	provides tables for e max 0.04 - 0.08 with design domain aids
Horizontal SSD on curve	use table (e 0.08, 60mph = 475', 114.78m)	use chart (e=0.08, 100 km/h = 160-219m)
curve radii	no min curve tables based on speed	shows tables based on speed and e max values
vertical SSD crest curve	use table (60 mph = 475', min K 160)	use table (100 km/h, min K 45-80)
vertical SSD sag curve	use table (60 mph = 475', min K 105) one option	use table (100 km/h, min K 18-25) 2 available options, comfort & headlight
lane balance	not mentioned	section dedicated to it
lane & route continuity & weaving	not mentioned	section dedicated to it
climbing lanes	not mentioned	section dedicated to it
passing lanes	not mentioned	section dedicated to it
truck escape ramps	not mentioned	section dedicated to it
lane widths	focuses on freeways, arterials & ramps	covers all types of roads based on design speed, road classification & volumes
shoulders	covered in a paragraph related mostly to freeways	section dedicated to it
medians	covered in a paragraph related mostly to freeways	section dedicated to it
guardrail	warrants based on 5 factors that are weighted	warrants based on length of need calculations, design speed and clear zones
interchanges	exit gore offset 8.23m (27')	exit gore offset 10.7 - 11.0 (AT uses 11.0)
	loop radius of 38^ (45.9m) with varying spiral lengths	many loop radii options for varying design speeds
ramp terminal spacing	not mentioned	section dedicated to it
interchange types	not mentioned	section dedicated to it
overall	offers guidance but is limited in scope	goes into more detail, offers background and tables to assist in design
	covers the basics of road design	covers the basics and then some
	relies on formulas and graphs for standards	relies on tables for standards with the formulas and graphs as backup
** interesting note, many of the aesthetics photos are identical between the 2 books		

4.0 Design Process

The design process followed in the development of both projects has remained essentially the same despite the Parsons project's short development period. Both projects went through a conceptual design phase (functional planning), a preliminary design phase to prove out the various aspects of the design and a detailed design phase which added the details to the design changing it into something that could be interpreted into construction. The major differences between the projects is best exhibited in how each was developed from the end of the conceptual stage to a project that was ready for tendering and construction.

4.1 Preliminary Design

4.1.1 Preliminary Surveys – Whitemud Drive

Major advances have been made in the collection of field data required for the accurate determination of the various design elements. Although the Dumpy Level had long evolved into self levelling instruments, data collection remained fairly tedious with data collection remaining a two man operation. Topographic (topo) surveys consisted of rod readings taken by the level person (lead surveyor) that were entered by hand into the level book for points field located and referenced to legal pins or other surveyed control points and tied down by distance and offset to a surveyed base line. Most topo surveys were taken along a cross section perpendicular to the base line with individual points picked at a consistent distance off of the base line or at the location of objects of concern. Detailed transit notes identified the location of each cross section, identified the particular object of concern, added noteworthy details and observations and included hand drawn sketches supporting the written description. Elevations were referenced to geodetic benchmarks with horizontal control coordinated to the NAD27 Datum.

Rod readings were reduced in the field with all level circuits tied back to a control point or bench mark to confirm accuracy. Point locations were reduced to coordinates by the designer in either grid or ground datum where an accurate location was critical. Non-critical measurements were usually plotted directly from the transit notes. Early on in the design of Whitemud Drive neither computers nor hand calculators were readily available. As a result all calculations were completed by hand or by using a manual desk top calculator. Rudimentary hand held calculators (four-function non programmable digital calculators were introduced about 1967 and were readily available in the early1970's). They made note reduction easier and the introduction of the Hewlett Packard HP-11 programmable calculator (introduced in 1981) greatly automated the process.

4.1.2 Preliminary Surveys – Parsons Interchange

The collection of topographic data has now evolved to the point where human involvement has been minimized. Data can now be collected by remote controlled drones flying a set pattern at a fixed altitude and transmitting data to a remotely located data base as it is collected. The data base can easily be programmed to reduce the notes into any desired format for further entry into a design data base. For the Parsons project LIDAR (light detection and ranging) data was collected by a commercial aircraft with the data collection equipment referencing both ground mounted base stations and global positioning through satellite communications. The data was collected to a vertical accuracy of 30 centimetres and a horizontal accuracy of 45 centimetres with a point density of 75 centimetres. The collected data was verified twice once by the LIDAR contractor and again independently by the design consultant. The verification was accomplished by comparing the airborne data to independently surveyed ground points. Data reduction was automated with point coordinates and elevations available to the designed in any requested format.

A separate GPS survey was completed to tie in points of interest with location and elevation provided in the same format as the LIDAR information. Predetermined identifiers entered into the system during the survey tagged a descriptor to each point taken in the field that carried through to the design for easy reference during base plan preparation.

As a LIDAR survey had been completed a short time before the project was initiated, the information was readily available on short notice.

4.1.3 Base Plan Preparation – Whitemud Drive

For the most part base plans for this project were prepared by hand on mylar in a multi stage process. The first step in the process was to create a reference grid reflecting the coordinate base used in the design. This grid was meticulously drawn on the back side of the plan sheet so that any eradication of entered information, which was to be placed on the front of the sheet, wouldn't also erase the grid. Particular attention was paid to developing the grid as at times the drawing sheet could be several metres long. As this was still in the Imperial era, it was not uncommon to be working on a mylar 18 feet (5.5 metres) long and 42 inches (1.07 metres) wide. In which case maintaining grid line accuracy was critical to producing an accurate plot of the design.

As well as the grid lines, permanent information such as property lines, bench marks, etc. were either plotted on the back or if an accurate plan was available, copied onto the backside of the mylar. This also applied to all of the pertinent data identified in the transit notes.

Plots of the base were very tricky to achieve and depended on both the quality of the printer and the skill of the operator. There were many occasions where heated words were exchanged over a torn or wrinkled original and plan. Plan reproduction was not something that could be demanded on the spur of the moment. There was always a supply of prepared grid sections that could be spliced into a roll as the necessity arose.

With the completion of this stage of the base the plan was read for the entry of design information. If a functional design review was warranted, a plot of the functional alignment was added to the base to facilitate the development of the roadway geometry. In the case of Whitemud Drive however, the design team proceeded directly with the determination of the roadway geometry.

4.1.4 Base Plan Preparation – Parsons Interchange

Base plan preparation for the Parsons project was a totally digital process. In this instance Microstation, GeoPac and InRoads were the design/drafting tools used. AutoCAD and the AutoCAD suite of tools would have produced a similar result.

All information was entered in individual "layers" so that they could easily be turned off to reduce file size. The process started with a Cadastral plan that was trimmed to reduce file size and to remove extraneous information. This was followed by GPS data and LYDAR data that had been sorted by descriptor and also stored on layers designated for particular data types. Whereas on the Whitemud project, original ground contours were not created at the base plan stage, the Parsons topographic data was processed through a terrain modeler to produce an original ground surface that was readily available to assist in route assessment as well as for quantity calculations in the detailed design phase.

Functional design information, which was prepared in accordance with the basic design criteria was added to the base plan information. This allowed the design team a final opportunity to critique, review and refine the functional design and to make any final conceptual changes prior to proceeding with the detailed design.

All of the entered information, used collectively or individually, formed the basis of the base plan.

4.2 Detailed Design

4.2.1 Whitemud Drive

a. Horizontal Alignment Design

Detailed design relied on a close interaction between the designer and draftsperson with the designer providing the specifics including point coordinates and roadway geometry and the draftsperson accurately placing that information on to the plan. Review consisted of confirmation that design standards were met but also relied heavily on visual observation to confirm the look and feel of the design. The scale that was used in the preparation of the plot and the ability to look at a large portion of the design at one time allowed this review process to be very effective.

Computer aided design was in its infancy and was not readily available during the early stages of the Whitemud Drive Project. One source was directly with IBM which operated and rented time on an IBM 360 at their local facility. The design team worked with IBM to run an early version of ICES CoGo software. This was an effective design tool that allowed the designer to work with incomplete alignments and solve for up to three unknowns at a time. Although trial and error was not eliminated, the time required to develop an alignment was greatly reduced. The process was not without some serious limitations however, including finding parking near IBM, writing the program to be run and probably the most challenging, entering the data on to the “punch cards” that had to be run through the card reader. This was not a task for the dyslexic or the heavy fingered designer. It did however, require a good understanding of the design criteria along with a thorough knowledge of complex trigonometry and the associated relationship of geometric shapes.

In the application of the information produced to the plan, the draftsperson used a variety of tools including scales of various calibration, a sturdy straight edge, a set of curve templates, ships templates, splines, whales, lettering tools, sets of high quality pens with a variety of nib widths and most importantly, good penmanship (a steady hand).

b. Vertical Alignment Design

As with the horizontal design, designing the roadway profiles required a sound understanding of relevance of design standards including stopping sight distance, vertical curve control, the relationship between horizontal and vertical curves and superelevation and the development of superelevation. Also as with horizontal design review, a good experienced eye was invaluable in design review sessions.

The development of ramp profiles was dependent on the accurate calculation of offset distances. This was and still is required in order to maintain a consistent crossfall as the surface width increases across the ramp terminal. Determination of the offset distances was simplified through the use of the CoGo software. Although the offset determination was not absolutely accurate it did provide consistency in the calculation of the offset profile.

The tools needed to prepare the profile drawing were the same as that required for the drafting of the horizontal design.

c. Quantity Determination

The determination of the various quantities for estimating and tendering purposes was tedious work requiring extensive measurement and calculation. Surface quantities were relatively straight forward requiring the determination of areas and depths. Calculations were more complex at ramp intersections where the shapes could be complex and a sound knowledge of geometric formulas was a definite asset.

Earthworks calculations required the most tedious work. Although a simple end area calculation, area determination was complicated as a result of constantly varying widths and depths. Large portions of each cross section could easily be determined through simple measurement. Tying off the irregular shape edges however, required more time and was completed using either a planimeter or simple strip scale which with practice was extremely efficient and quite accurate.

d. Final Product

Production of individual sheets for tender purposes was a combination of art and science. On the completion of the design base individual sheets were produced by preparing photographic images of the original. This allowed for the preparation of individual sheets at any required scale. The original would be masked to outline each sheet, photographed and reproduced on Mylar. These in turn would be reproduced and used as the base for details such as point elevations, pavement markings, signing, signals etc. to be assembled into the final sets used for tendering and construction.

4.2.2 Parsons Interchange

a. Geometric Design

The Parsons Interchange design was completed using the GeoPac software package. Working within a software suite of this type results in an interactive design process where a change to one element is automatically carried across to all other interconnected elements. For example a shift in alignment will reposition the cross sections along that element. Similarly a profile adjustment will result in recalculated contours. With this design process, a thorough knowledge of the software is essential to the successful completion of the design.

With the Parsons Interchange project, the design process began with the entry of the geometric elements to the base plan beginning with the main line alignments. Using the functional plan alignment as a base, the individual geometric elements were verified for conformance with the design criteria (roadway classification) such as design speed, lane and shoulder widths, etc. that had been predetermined. As a result of the complexity of the interchange and the topographic challenges, profile development had to occur at the same time in order to ensure that offsets between the horizontal elements was sufficient to accommodate required side slopes, that the lengths of the individual elements were sufficient to address maximum grade limitations. As the design progressed cross section elements were added defining ditch profiles, drainage courses, backslope ratios, etc. Following the addition of the roadway structure details (GBC and ACP structures) a final check was made to ensure that all design criteria was met or exceeded. This in turn led to the creation of the terrain model and the calculation of quantities.

b. The Final Product

All of the design elements were created digitally on individual layers within GeoPac and saved in their specific layer for use as required. With the completion of the detailed design work, the overall project was cut digitally into sheet sized sections, in a manner reminiscent of the Whitemud project, for insertion into individual sheets for tender and construction purposes. From this point forward care had to be taken to ensure that a change to particular element was reflected back through the entire set to ensure continuity throughout the design.

5.0 Closure

A study of the evolution of geometric design from Whitemud to Parsons shows the progression from an intensive hands on design involvement to a technical process relying more on a knowledge of the design software than design standards. Programming design criteria into the software may produce a greater degree of design consistency but it also removes a level of accountability from the designer. A more serious result may be the loss of experience and understanding that was developed during the period of hands-on design.

The Whitemud Drive design team was required to know the roadway classification, the associated standards and the mathematical tools required to achieve those standards. Utilizing the pre-packed software program on the Parsons Interchange project along with other advances in data gathering enabled the designer to use a significantly larger amount of data than would be possible without the technology. The benefit of that data however has to be weighed against an understanding of how the data is used in the software and how the software is applying the design criteria.

The final printed product resulting from the completion of the design of each project was surprisingly similar. It is in the process of achieving that result that the differences can be noted. Along with understanding the advances in the automation of the design process, the roadway design community has to work toward advancing design standards in terms of sustainability, cost and safety.

6.0 Exhibits

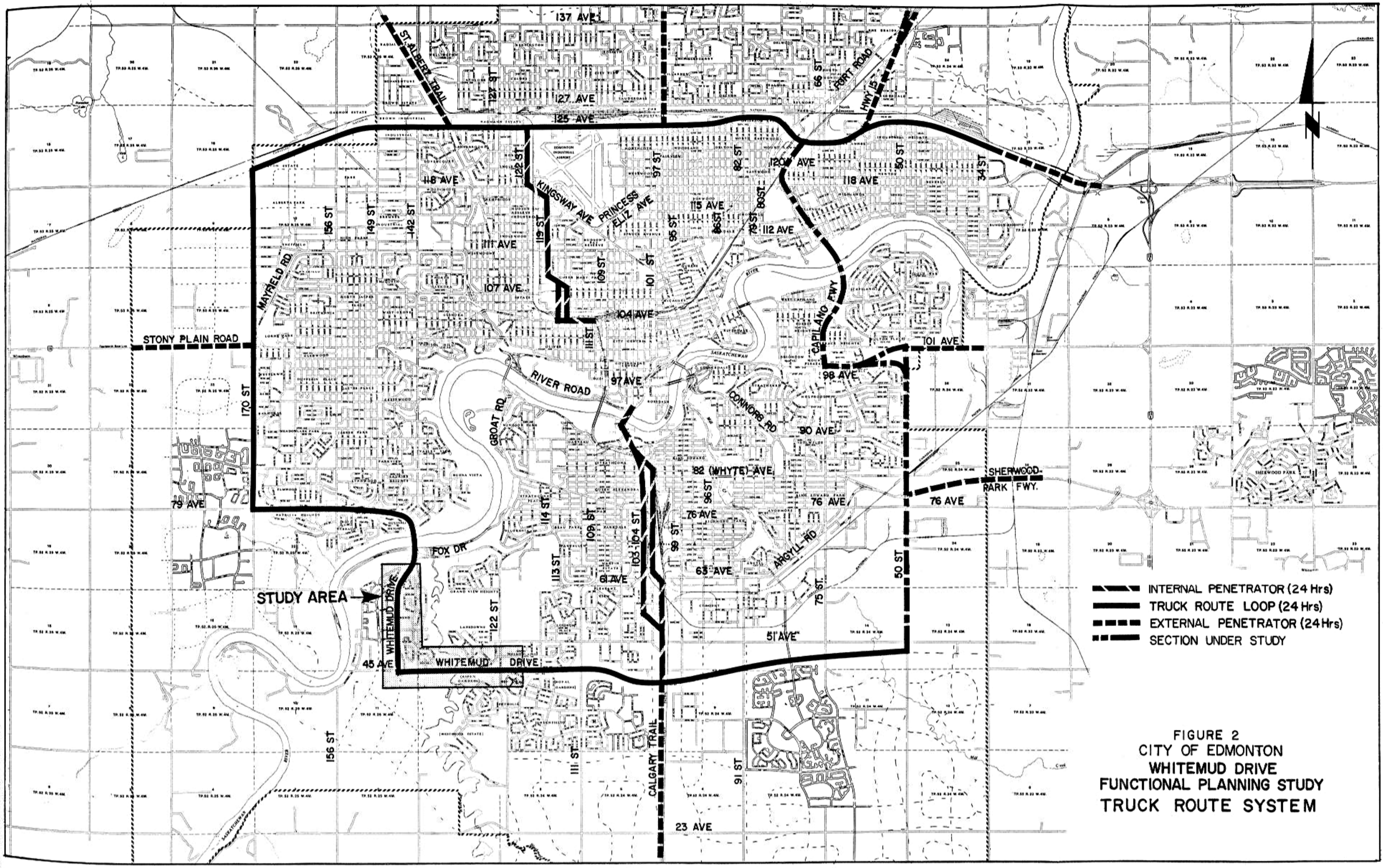


FIGURE 2
CITY OF EDMONTON
WHITEMUD DRIVE
FUNCTIONAL PLANNING STUDY
TRUCK ROUTE SYSTEM

Exhibit 1

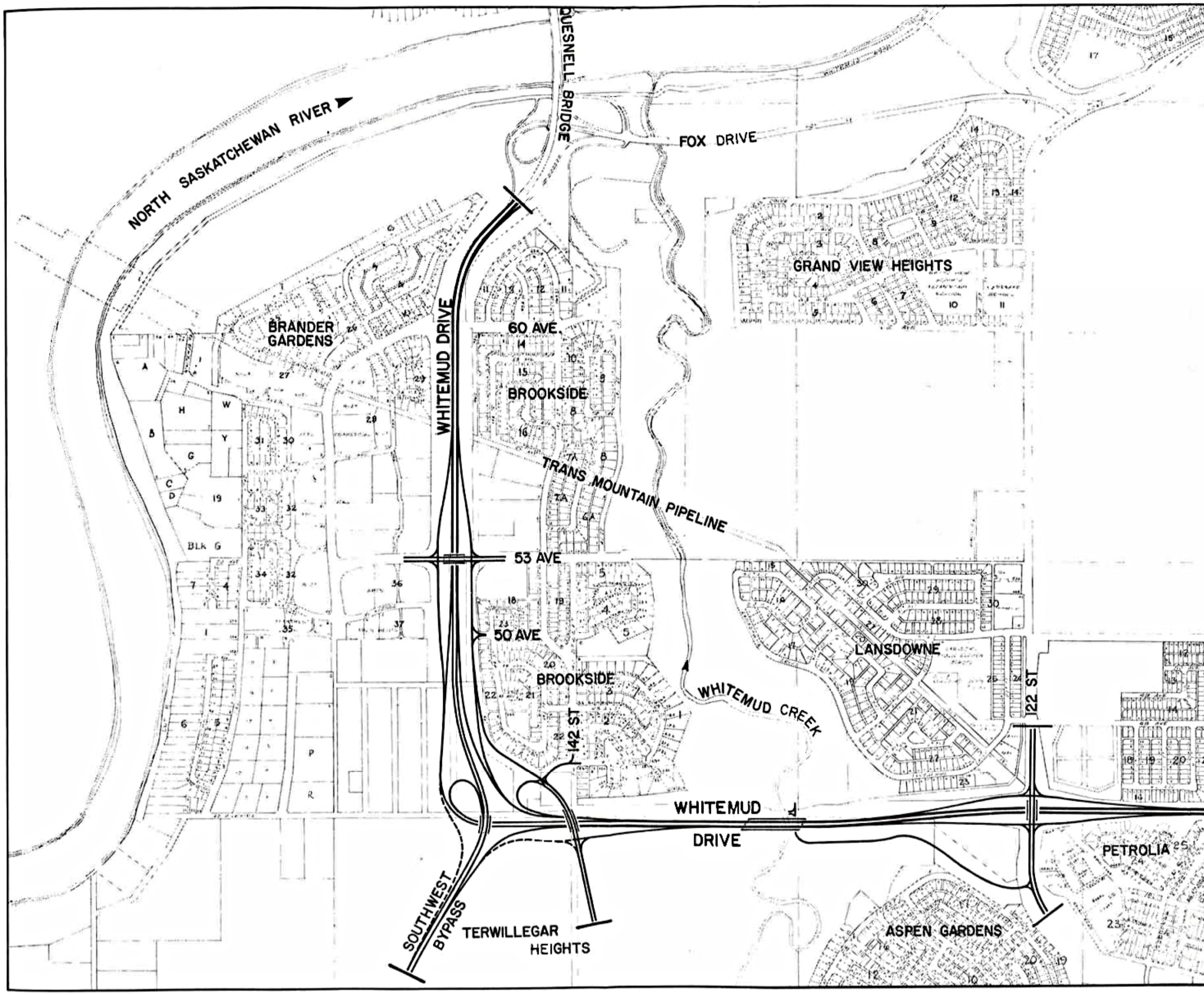


FIGURE 3
CITY OF EDMONTON
WHITEMUD DRIVE
FUNCTIONAL PLANNING STUDY
RECOMMENDED ULTIMATE PLAN
KEY PLAN

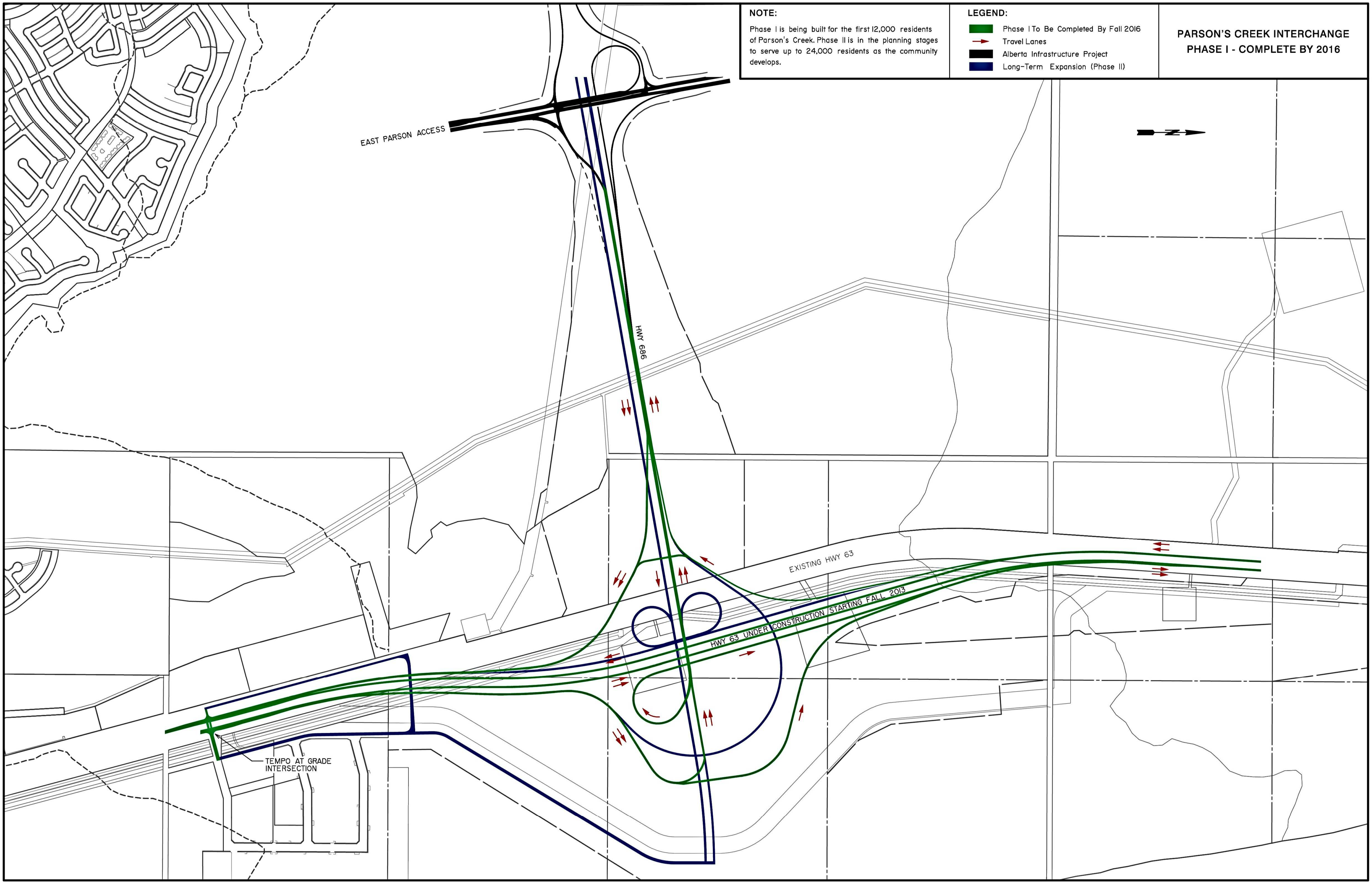
PARSON'S CREEK INTERCHANGE
PHASE I - COMPLETE BY 2016

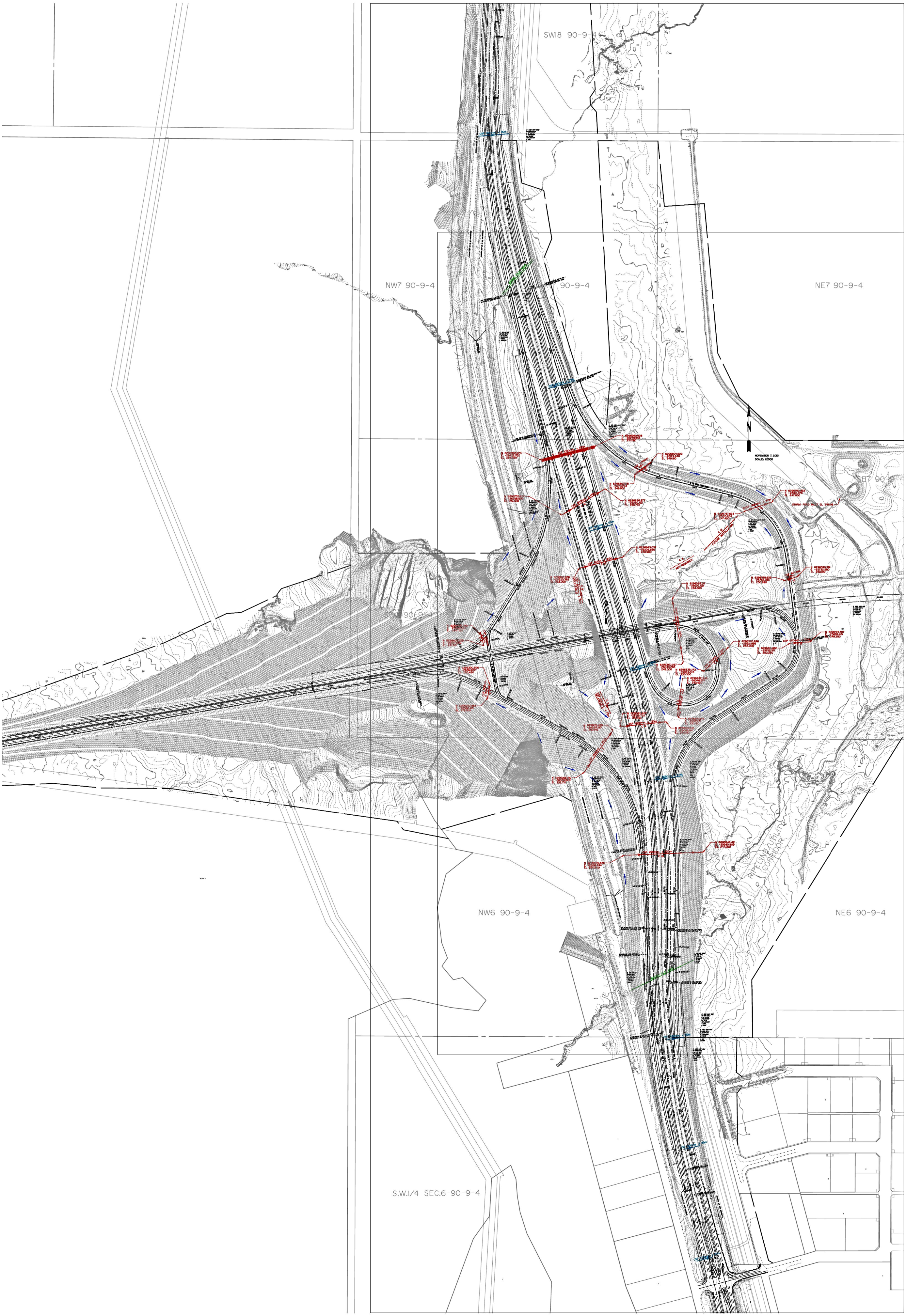
NOTE:

Phase I is being built for the first 12,000 residents of Parson's Creek. Phase II is in the planning stages to serve up to 24,000 residents as the community develops.

LEGEND:

- Phase I To Be Completed By Fall 2016
- Travel Lanes
- Alberta Infrastructure Project
- Long-Term Expansion (Phase II)





SW18 90-9-4
NW7 90-9-4
90-9-4
NE7 90-9-4
NW6 90-9-4
NE6 90-9-4
PIPELINE/UTILITY CORRIDOR
S.W.1/4 SEC.6-90-9-4

7.0 References

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2. The Transportation Association of Canada (TAC) “Geometric Design Guide for Canadian Roads”
3. The Department of Highways and Transport Province of Alberta “Urban Highway Design Guide (1970)”
4. Alberta Transportation “Highway Geometric Design Guide, 1999”
5. City of Edmonton “Whitemud Drive Functional Planning Study, 1974”
6. City of Edmonton “Construction Drawings for Whitemud Drive, Stage II Paving, 145 Street to 122 Street, Contract No. 783”
7. Alberta Transportation (63:11; 63:12) Parsons Interchange and Highway 686:20 East West Connector Road Work