COLORADO

DOT

DEPARTMENT OF TRANSPORTATION

METRIC CONVERSION MANUAL

January 1994

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Preface

The United States must commit to metrication. Two overwhelming factors, the adoption of the metric system by the remainder of the world and the changing global economy, mandate that this nation must change.

This Guide has been written to provide an explanation of the need for the change, and to serve as a resource to help bridge the gap between building roads in the English-based system of units and the Metric system. It is intended that this guide be used as a reference manual for CDOT employees in the Right-Of-Way, Design, Bridge, Materials, Traffic, Maintenance, Planning, and Environmental areas.

The AASHTO Metric Task Force requested that each AASHTO Highway Subcommittee and task force develop a position and recommendations addressing metrication items in their areas of responsibility.

The AASHTO committees and task forces are attempting to address the metrication impacts in all areas of highway transportation. It is possible that different task forces will adopt different criteria for the same items. It may be that as the highway industry begins to use the criteria, they may be revised. Thus, some metric criteria in this guide may require change at a later date.

The reader is advised to seek the most recent version of AASHTO policy on these issues.

Introduction

The United States is converting its transportation system to the metric system, and the date that the Federal Highway Administration has established is September 30,1996. After that date, no highway projects may be paid for with Federal Lands Highway or Federal-aid Highway funds unless the plans, specifications and estimate (PS&E) are all in metric units.

LEGAL BASIS FOR HIGHWAY CONVERSION

Metric Conversion Act of 1975 & Omnibus Trade and Competitiveness Act of 1988

The impetus for the change came from Congress. *The Metric Conversion Act of 1975* encouraged metrication, but left it as a voluntary activity. As a consequence, virtually no metrication took place. The *Omnibus Trade and Competitiveness Act of 1988* amended the 1975 Act to designate the modern metric system (System International or SI) as the preferred system of weights and measures for U.S. trade and commerce. It also requires each federal agency to convert to metric, and requires each federal agency to use metric in its procurements, grants, and other business-related activities to the extent economically feasible.

These acts did not mandate that individual states, cities, counties, industries, or other organizations convert to metric. However, these entities cannot obtain federal roadway money unless they use metric. It is probable that all will convert to metric to remain eligible for road funds, and it is best that we all convert quickly using consensus guidelines.

Executive Order 12770

In addition to the congressional legislation, Executive Order 12770 was issued in July 1991. It required each federal agency to adopt a metric conversion plan by November 30,1991. Among the other provisions of the executive order were instructions that the Department of Commerce was to lead the metrication effort.

The Federal Highway Administration Metric Transition Plan was approved by the Secretary of Transportation in October 1991. It laid out procedures and administrative policies for the conversion, and established certain milestone dates. For example, after September 30, 1992, FHWA publications and correspondence were to use metric as the primary system of units for all measurements. FHWA manuals and documents were to be systematically revised and republished in metric so they would be available to guide the conversion. The key date is September 30, 1996. All construction contracts advertised for bids after that date must contain only metric measurements for any federal lands highway or federal-aid highway construction project.

U.S. DOT Metric Conversion Planning Guidelines

On May 8,1990, the U.S. Department of Transportation (U.S. DOT) issued Order 1020.1C which established policy and administrative procedures for the transition. A change to the order was published in January of 1991. It was further amended and issued as Order 1020.1D on March 23,1992. The Order defines SI as the official metric system, and refers to ASTM E 380 and several other industry standards and documents for guidance on conversion from U.S. units to SI.

The U.S. DOT order requires agencies to develop plans for conversion to SI to the extent practical. These plans are to include specific dates for changeover to SI in procurements, grants and other business-related activities. U.S. DOT is to participate in the Interagency Committee on Metric Policy, and a U.S. DOT Metric Coordination Committee was created. The Order also contains guidance to U.S. DOT agencies to assist them in completing their conversion plans.

The U.S. DOT Metric Coordinator indicated in early 1992, "It is now the policy of the Department to pursue and promote an orderly changeover to the SI system. He also noted that there were nine comprehensive metric conversion plans in place for the nine U.S. DOT agencies, including the Federal Highway Administration (FHWA).

NECESSITY FOR CONVERSION

As of 1990, there were only three nations that had not converted to metric: Burma, Liberia, and the United States. Subsequently, these three nations face serious difficulties in exchanging information with other nations, in conducting international trade, and in performing engineering or construction work with other countries.

The current global economy presents another serious difficulty. At the end of World War II, the United States was the center of world commerce. At that time America produced 75% of the world's products; today that value has shrunk to 25%. The world economy has changed rapidly, and industry in the United States is being placed at an increasing disadvantage because of its non-metric system of measurements. American firms are sometimes excluded from doing international business when unable to measure goods in metric terms. A few facts will help put this into perspective:

- The European Community (EC) is composed of 12 nations and is potentially the world's most powerful market, surpassing the United States. The EC specified that products with non-metric labels will not be permitted for sale after 1992.

- The largest U.S. trading partners, Canada and Mexico, are predominantly metric countries.

- Japan has identified the non-metric nature of U.S. products as a specific barrier to the importation of U.S. goods.

BENEFITS OF METRIC CONVERSION

International Acceptance

Metric is the world's measurement language. Fewer and fewer cultures are familiar with U.S. measurement units, and many are increasingly unwilling to overcome this hurdle in order to purchase and utilize American goods. The costs associated with doing business in this country (labor, taxes, tariffs, etc.) make it difficult for U.S. firms to produce their goods at prices which are attractive to other nations. They do not need the additional handicaps of non-standard sizes and a measurement system which is the exception rather than the rule.

International Competitiveness

Greater industrial efficiency and international competitiveness are available through the metric system. Canada has already converted to metric. The Canadian Metric Association reported that metric produced direct benefits in terms of reduction in design costs and times, increased construction efficiencies, and improved material and component dimensioning techniques.

Private Sector Conversions Already Underway

Some U.S. businesses have already converted. One of the earliest industries to be affected by metrics was the automobile manufacturing sector. General Motors made an early decision that it must convert its manufacturing. Surprisingly, total conversion costs for GM were less than 1% of their original estimates. IBM and Otis Elevator are other examples of firms that have switched to metric, in this case to increase international competitiveness and to reduce their parts inventories. The wood industry has converted to metric for international sales. Timber products are being shipped overseas in metric sizes.

Opportunity to Consolidate or Redesign

The conversion process allows industries an opportunity to rethink their designs and to incorporate efficient practices. One way to do this is to designate fewer product sizes, reducing inventories and eliminating some manufacturing equipment. Rationalization of fastener sizes during metric conversion allowed IBM to reduce its number of fasteners from 30,000 to 4,000. The liquor industry reduced the number of container sizes from 53 to 7 during its metric conversion.

International Market for Engineering Services

Many American design and construction firms have already begun using metric units for their foreign work. Foreign billings for American architecture/engineering contracting firms amounted to $3.2 billion in 1989, a substantial amount of business.

Simplicity

Perhaps the strongest argument in favor of the metric system is its simplicity of use. It is completely decimal based. There is no need to convert from one type of measurement to another type of measurement. For example, inches do not have to be converted to feet. Feet do not have to be converted to miles. Tablespoons do not have to be converted to cups. There is no requirement to change 27 feet, 8 1/4 inches into the equivalent number of yards.

The universal experience of every country that has converted has been that the metric system was easier to learn and easier to use than the convoluted system currently being used in the United States. It is just getting the transition underway that is hard. Once the mental leap has been made, calculations are much, much easier.

One Unit for Each Property

One of the greatest advantages is that there is only one unit for measuring each physical property. For example, pressure may be measured by psi, psf, kips/sf, inches of mercury or other units in the conventional U.S. system. The SI system has only one unit for pressure, the pascal. Another example involves power, which may be measured in hp, btu's, watts, and several other terms. In SI, it is measured only in watts. Therefore, metric is a more coherent system in that only one unit is used for each physical quantity and there are no conversion factors to remember.

Conclusion

Metric's coherency, its simple base units, and its use of decimal arithmetic make it an especially logical and useful measurement system.

The American construction community is able to meet the metric conversion challenge in federal construction, and it is in our long term strategic interest to do so.

There will be initial effort involved. Firm resolve, close cooperation between the public and private sectors, and creative application of our extensive talent and expertise will allow the challenge to be successfully met.

CHAPTER ONE

Metric Units, Terms, Symbols, and Conversion Factors

BASIC METRIC

Base Units

There are seven metric base units of measurement, six of which are used in design and construction (The seventh, mole, is the amount of molecular substance and is used in physics).

Quantity	Unit	Symbol
length	meter	m
mass*	kilogram	kg
time	second	s
electric current	ampere	A
temperature	kelvin	K
luminous intensity	candela	cd

*"Weight" in common practice often is used to mean "mass".

Celsius temperature (°C) is more commonly used than kelvin (K), but both have the same temperature gradients. Celsius temperature is simply 273.15 degrees warmer than kelvin, which begins at absolute zero. For instance, water freezes at 273.15 K and at 0 °C, while it boils at 373.15 K and at 100 °C. To move between Celsius and Kelvin, add or subtract 273.15.

Decimal Prefixes

Only two decimal prefixes are commonly used with the base units in design and construction:

Prefix	Symbol	Order of Magnitude	Expression
kilo	k	10^3	1000 (one thousand)
milli	m	10^{-3}	0.001 (one thousandth)

The prefixes mega (M) for one million (10^6), giga (G) for one billion (10^9), micro (μ) for one millionth (10^{-6}), and nano (n) for one billionth (10^{-9}) are used in some engineering calculations.

Decimal prefixes to the tertiary power of 10 are preferred. The prefixes deci (d) for one tenth (10^{-1}), centi (c) for one hundredth (10^{-2}), deca (da) for ten (10^1), and hecto (h) for one hundred (10^2) have limited application in construction.

BASIC METRIC (Cont'd)

Plane and Solid Angles

The radian (rad) and steradian (sr) denote plane and solid angles. They are used in lighting work and in various engineering calculations. In surveying, the units degree (°), minute ('), and second (") continue in use.

Derived Units

Fifteen derived units with special names are used in engineering calculations:

Quantity	Name	Symbol	Expression
frequency	hertz	Hz	$Hz = s^{-1}$
force	newton	N	$N = kg \cdot m/s^2$
pressure, stress	pascal	Pa	$Pa = N/m^2$
energy, work, quantity of heat	joule	J	$J = N \cdot m$
power, radiant flux	watt	W	$W = J/s$
electric charge, quantity	coulomb	C	$C = A \cdot s$
electric potential	volt	V	$V = W/A$ or J/C
capacitance	farad	F	$F = C/V$
electric resistance	ohm	Ω	$\Omega = V/A$
electric conductance	siemens	S	$S = A/V$ or Ω^{-1}
magnetic flux	weber	Wb	$Wb = V \cdot s$
magnetic flux density	tesla	T	$T = Wb/m^2$
inductance	henry	H	$H = Wb/A$
luminous flux	lumen	lm	$lm = cd \cdot sr$
illuminance	lux	lx	$lx = lm/m^2$

Liter, Hectare, and Metric Ton

The liter (L) is the measurement for liquid volume. The hectare (ha) is a metric measurement used in surveying. The metric ton (t) is used to denote large loads such as those used in excavating.

Pronunciation

candela	Accent the second syllable, can-**dell**-ah.
hectare	Accent the first syllable: **heck**-tare. The second syllable rhymes with **care**.
joule	Rhymes with **pool**.
kilometer	Accent the first syllable: **kill**-o-meter.
pascal	Rhymes with **rascal**.
siemens	Sounds like **seamen's**.

BASIC METRIC (Cont'd)

Rules for Writing Metric Symbols and Names

- Print unit symbols in upright type and in lower case except for liter (L) or unless the unit name is derived from a proper name.
- Print unit names in lower case, even those derived from a proper name.
- Print decimal prefixes in lower case for magnitudes 10^3 and lower (i.e. k, m, μ, and n) and print the prefixes in upper case for magnitudes 10^6 and higher (i.e. M and G).
- Leave a space between a numeral and a symbol (write 45 kg or 2.37 mm, not 45kg or 2.37mm). *Exception:* No space is left between the numerical value and the symbols for degree, minute and second of plane angle, and degree Celsius (write 45° or 20°C, not 45 ° or 20 °C or 20° C.
- Do not use a degree mark (°) with kelvin temperature (write K, not °K).
- Do not leave a space between a unit symbol and its decimal prefix (write kg, not k g).
- Do not use the plural of unit symbols (write 45 kg, not 45 kgs), but do use the plural of written unit names (several kilograms).
- For technical writing, use symbols in conjunction with numerals (the area is 10 m^2); write out unit names if numerals are not used (carpet is measured in square meters). Numerals may be combined with written unit names in nontechnical writing (10 meters).
- Indicate the product of two or more units in symbolic form by using a dot positioned above the line ($kg \cdot m \cdot s^{-2}$).
- Do not mix names and symbols (write N·m or newton meter, not N·meter or newton·m).
- Do not use a period after a symbol (write "12 g", not "12 g.") except when it occurs at the end of a sentence.

BASIC METRIC (Cont'd)

Rules for Writing Numbers

- Always use decimals, not fractions (write 0.75 g, not ¾ g).
- Use a zero before the decimal marker for values less than one (write 0.45 g, not .45 g).
- Use spaces instead of commas to separate blocks of three digits for any number over four digits (write 45 138 kg or 0.004 46 kg or 4371 kg). Note that this does not apply to the expression of amounts of money.
- In the United States, the decimal marker is a period; in other countries a comma usually is used.

Conversion and Rounding

- When converting numbers from inch-pounds to metric, round the metric value to the same number of digits as there were in the inch-pound number (11 miles at 1.609 km/mi equals 17.699 km, which rounds to 18 km).
- Convert mixed inch-pound units (feet and inches, pounds and ounces) to the smaller inch-pound unit before converting to metric and rounding (10 feet, 3 inches = 123 inches; 123 inches x 25.4 mm/in = 3124.2 mm; round to 3124 mm).
- In a "soft" conversion, an inch-pound measurement is mathematically converted to its exact (or nearly exact) metric equivalent. With "hard" conversion, a new rounded, rationalized metric number is created that is convenient to work with and remember.

Soft Metric

- Soft Metric means "No Physical Change". This implies the product in question will not be physically modified to be used in a metric project.
- All that is required is that the product literature and engineering data on these products be available with metric dimensions. It is acceptable if product literature contains both metric and english dimensions. Since product literature costs can be substantial, firms without metric product literature need only develop a supplement to their existing literature. Supplements will be accepted as submittals for an interim period.
- There is no problem with competitive availability of soft converted products on a metric project, since these same products are competitively available today.
- In the future, as standard international metric product sizes are developed by ISO (International Standard Organization) or another standards organization, these products may undergo modification to be compatible in the world market.

Hard Metric

- Hard Metric means "Product Requires Physical Change. The product in question must be physically modified in order to be efficiently utilized in a metric project, which is planned on a metric grid.

- A handful of currently used construction products must undergo hard conversion to new metric sizes.

Visualizing Metric

A few basic comparisons are worth remembering to help visualize metric:

- One millimeter is about 1/25 inch or slightly less than the thickness of a dime.
  One meter is the length of a yardstick plus about 3-1/3 inches.
  One gram is about the mass (weight) of a large paper clip.
  One kilogram is about the mass (weight) of a softbound model building code book (2.2 pounds).
  One liter is about the volume of a 4 inch cube (100 mm x 100 mm x 100 mm). One liter of water has a mass of 1 kilogram.

- One inch is just a fraction (1/64 inch) longer than 25 mm (1 inch = 25.4 mm; 25 mm = 63/64 inch).
  Four inches are about 1/16 inch longer than 100 mm (4 inches = 101.6 mm; 100 mm = 3-15/16 inches).
  One foot is about 3/16 inch longer than 300 mm (12 inches = 304.8 mm; 300 mm = 11-13/16 inches).
  Four feet are about 3/4 inch longer than 1200 mm (4 feet = 1219.2 mm; 1200 mm = 3 feet, 11¼ inches).

- The metric equivalent of a typical 2-foot by 4-foot ceiling grid is 600 x 1200 mm, so metric ceiling tiles and lighting fixtures are about 3/8 inch smaller in one dimension and 3/4 inch smaller in the other.

- Similarly, the metric equivalent of a 4 by 8 sheet of plywood or drywall is 1200 x 2400 mm, so metric sheets are about 3/4 inch narrower and 1-1/2 inches shorter.

- "Rounding down" from multiples of 4 inches to multiples of 100 mm makes dimensions exactly 1.6 percent smaller and areas about 3.2 percent smaller. About 3/16 inch is lost in every linear foot.

BASIC METRIC (Cont'd)

Conversion Rules

- Wherever possible, convert measurements to rounded, rationalized "hard" metric numbers. For instance, if anchor bolts are to be embedded to a depth of 10 inches, the exact converted length of 254 mm might be rounded to either 250 mm (9.84 inches) or 260 mm (10.24 inches). The less critical the number, the "rounder" it can be, but ensure that allowable tolerances or safety factors are not exceeded. When in doubt, stick with the exact "soft" conversion.

- Round to "preferred" metric numbers. While the preferred numbers for the "1 foot = 12 inches" system are, in order of preference, those divisible by 12, 6, 4, 3, 2 and 1, preferred metric numbers are, in order of preference, those divisible by 10, 5, 2 and 1 or decimal multiples thereof.

- Use hand calculators or software conversion programs that convert inch-pounds to metric. They are readily available and are indispensable to the conversion process. Simply check with any store or catalogue source that sells calculators or software.

- Be careful with the decimal marker when converting areas and volumes; metric numbers can be significantly larger than inch-pound numbers (a cubic meter, for instance, is one billion cubic millimeters).

LENGTH, AREA, VOLUME AND TEMPERATURE

One metric unit is used to measure length, area, and volume in most design and construction work:

- meter (m).

Rules for Linear Measurement (Length)

- Use only the meter and millimeter in building design and construction.
- Use the kilometer for long distances and the micrometer for precision measurements.
- Avoid use of the centimeter.
- For survey measurement, use the meter and the kilometer.

Rules for Area

- The square meter is preferred.
- Very large areas may be expressed in square kilometers and very small areas, in square millimeters.
- Use the hectare (10 000 square meters) for land and water measurement only.
- Avoid use of the square centimeter.
- Linear dimensions such as 40 x 90 mm may be used; if so, indicate width first and height second.

Rules for Volume and Fluid Capacity

- Cubic meter is preferred for volumes in construction and for large storage tanks.
- Use liter (L) and milliliter (mL) for fluid capacity (liquid volume). One liter is 1/1000 of a cubic meter or 1000 cubic centimeters.
- Since a cubic meter equals one billion cubic millimeters, the cubic decimeter and cubic centimeter may be used in limited applications, since they are multiples of 1000 in volume measurement.

LENGTH, AREA, VOLUME AND TEMPERATURE (Cont'd)

Area, Length, and Volume Conversion Factors

Quantity	From Inch-Pound Units	To Metric Units	Multiply By
Length	mile	km	1.609 344
	yard	m	0.914 4
	foot	m	0.304 8
		mm	304.8
	inch	mm	25.4
Area	square mile	km^2	2.590
	acre	m^2	4 046.856
		ha (10 000 m^2)	0.404 685 6
	square yard	m^2	0.836 127 36
	square foot	m^2	0.092 903 04
	square inch	mm^2	645.16
Volume	acre foot	m^3	1 233.49
	cubic yard	m^3	0.764 555
	cubic foot	m^3	0.028 316 8
	cubic foot	cm^3	28 316.85
	cubic foot	L (1000 cm^3)	28.316 85
	100 board feet	m^3	0.235 974
	gallon	L (1000 cm^3)	3.785 41
	cubic inch	cm^3	16.387 064
	cubic inch	mm^3	16 387.064

NOTE: Using the U.S. survey foot definition, one meter = 3937/1200 feet.

Temperature Conversion Table

Temperature	
Metric Value (°C)	U.S. Equivalent (°F)
-51	-60
-40	-40
-35	-31
-34.4	-30
-17.8	0
-17.0	1
-1.1	30
0	32
1.7	35
3.4	40
7.2	45
20	68
40	104
46.1	115
48.9	120
148.9	300

CIVIL AND STRUCTURAL ENGINEERING

The metric units used in civil and structural engineering are:

- meter (m)
- kilogram (kg)
- second (s)
- newton (N)
- Pascal (Pa)

Rules for Civil and Structural Engineering

- There are separate units for mass and force.

- The kilogram (kg) is the base unit for mass, which is the unit quantity of matter independent of gravity.

- The newton (N) is the derived unit for force (mass times acceleration, or $kg \cdot m/s^2$). It replaces the unit "kilogram-force" (kgf), which should not be used.

- Do not use the joule to designate torque, always use newton-meter ($N \cdot m$).

- The pascal (Pa) is the unit for pressure and stress. The term "bar" is not a metric unit and should not be used.

- Structural calculations should be shown in MPa or kPa.

- Plane angles in surveying (cartography) will continue to be measured in degrees (either decimal degrees or degrees, minutes, and seconds) rather than the metric radian.

- Slope is expressed in non-dimensional ratios. The horizontal component is shown first and then the vertical. For instance, a rise of one meter in four meters is expressed as 4:1. The units that are compared should be the same (meters to meters, millimeters to millimeters, etc.).

- For slopes less than 45°, the vertical component should be unitary (for example, 20:1). For slopes over 45°, the horizontal component should be unitary (for example, 1:5).

Civil and Structural Engineering Conversion Factors

Quantity	From Inch-Pound Units	To Metric Units	Multiply By
Mass	lb kip (1000 lb)	kg metric ton (1000 kg)	0.453 592 0.453 592
Mass/unit length	plf	kg/m	1.488 16
Mass/unit area	psf	kg/m^2	4.882 43
Mass density	pcf	kg/m^3	16.018 5
Force	lb kip	N kN	4.448 22 4.448 22
Force/unit length	plf klf	N/m kN/m	14.593 9 14.593 9
Pressure, stress, modulus of elasticity	psf ksf psi ksi	Pa kPa kPa MPa	47.880 3 47.880 3 6.894 76 6.894 76
Bending moment, torque, moment of force	ft-lb ft-kip	N·m kN·m	1.355 82 1.355 82
Moment of mass	lb-ft	kg·m	0.138 255
Moment of inertia	$lb\text{-}ft^2$	$kg \cdot m^2$	0.042 140 1
Second moment of area	in^4 ft^4	mm^4 m^4	416 231 0.008 63
Section modulus	in^3	mm^3	16 387.064
Temperature	°F	°C	5/9(°F - 32)

METRIC PROJECT DEFINITION

A project is "metric" when:

- Specifications show SI units only
- Drawings show SI units only
- Construction takes place in SI units only
- Inspection occurs in SI units only
- Cost estimating is based on SI units only

This does not imply that construction products must change. Over 95% of the products used in construction today will undergo no physical change at all during the metric transition. All that will occur is that the dimensions of the product will be identified in drawings, specifications, and on product literature in metric units, a process called soft conversion.

There are a handful of products that must undergo a physical change now in order to be efficiently used in metric construction. This process is called hard conversion. As international standards are developed for more products, American products will then be hard converted to those sizes, to enhance their export potential.

Dual Dimensions

Dual Dimensions shall not be used on metric projects.

Dual Dimension example: 102 mm (4 inches)

Dual dimensioning is a wasted effort. It has no effect in construction documents. When English measurements are present, readers will use them and will ignore the metric measurement. *Exception:* In some cases dual dimensions will be used in certain Right-Of-Way documents (For more specific information, see the Right-Of-Way "Design/Plan Preparation" section of Chapter 2).

An exact analogy is appliance directions given in English and French. Most English-speaking people will ignore the French instructions, and vice versa.

Summary

It is most important that drawings and specifications be metric exclusively. It is of secondary importance if measurements are hard or soft metric.

When documents contain SI measurements only, the reader will learn metric in order to execute the work.

CHAPTER TWO

Right-Of-Way

The following standards are given as a guide to the conversion of Right-of-Way activities to the Metric system and can be used as guidance on how site plans and topographic maps are to be executed.

PRELIMINARY SURVEY

The three primary federal agencies involved in the production of survey information for public use are the National Geodetic Survey (NGS) in the Department of Commerce, the U.S. Geological Survey (USGS) in the Department of Interior, and the Bureau of Land Management (BLM) in the Department of Interior. All of these agencies are converting their data to metric compatible formats.

The NGS, which maintains a database of horizontal and vertical survey control points, has converted to metric. The North American Datum (NAD) of 1983 and the North American Vertical Datum (NAVD) of 1988 recently replaced the older NAD '27 and National Geodetic Vertical Datum (NGVD) 1929 datums, which were less accurate.

Because Colorado has a High Accuracy Reference Network (HARN), the latest datum shall be known as the NAD '83 (1992), based on a readjustment of the classical network in Colorado. This reduces the ± 1 meter error in the NAD of 1983 to ± 0.00 m. The NAVD of 1988 is now NAVD '88 (1992).

The USGS produces topographic maps and digital products which are based upon NAD '27 geodetic coordinates and NGVD '29 elevations. Topographic maps and related digital data are best used for location studies in the preliminary stages of design projects. These maps are, in most cases, not accurate enough for final design and engineering design work.

The BLM is in the process of converting all public land survey/records to a geodetic coordinate database which can be expressed in metric units.

Surveyors and engineers working with these products and maps need to be aware of the datums portrayed on the maps. When performing coordinate transformations, one should proceed with caution as local variations have been discovered.

The Global Positioning System (GPS) has proven to be an efficient and useful tool for performing preliminary surveys. The GPS methods yield coordinates in the World Geodetic System (WGS) 1984, which for all practical and engineering purposes is the same as NAD '83 (1992) and is expressed in metric units. With technological advancements in GPS equipment and software, the metric-based NAD '83 (1992) datum is well-suited as the datum to use for resource management and inventory, survey control, engineering projects, Geographic Information Systems, and Land Information Systems well into the twenty-first century.

Colorado survey personnel will be using NAD '83 (1992) only.

Units

Quantity	Unit	Symbol
length	kilometer, meter	km, m
area	square kilometer hectare (10,000 m^2) square meter	km^2 ha m^2
plane angle	degree (non-metric) minute (non-metric) second (non-metric)	° ' "

Surveying

- The definition of the U.S. Survey Foot dictates the following conversions: 0.304800610 m/ft., 2.54000508 cm/in., 39.37 in./m, and 1 K/3280.8333 ft.
- The 100 foot survey station shall be replaced with the 1 kilometer station.
- All survey angular measurements shall continue to be given in Degrees, Minutes, and Seconds.
- All survey distance measurements shall be done in meters.
- All new or surveyed dimensions on Right-of-Way plans or survey plats shall be given in metric units. Recorded deed distances shall be shown in parenthesis in the units recorded, such as feet, rods, or chains.
- After switching to metric units, all set 3's and SDR33 data collectors must be taken to the NOAA baseline for checking and verification before being used on a project. The data collector and set 3's must be checked as a unit to prescribed parameters. Send copies of the calibration data to the Survey Coordinator's office upon completion. Those performing the calibration should experiment with ppm calculations and temperature and pressure readings after the calibration procedure, but before leaving the baseline, to get a feel for the impact of changing ppms on the distance measurements in meters.

PRELIMINARY SURVEY (Cont'd)

Surveying (Cont'd)

Control Surveys

- Traverse Methods (Monument names remain the same in miles until kilometer posts are installed in the field)
  - Measure HI in meters
  - Measure distances under 200' chained
  - Measure angles in DD MM SS
  - Measure distance in meters (sct and data collector)
  - Single line tolerances go to ±0.008 m
  - Measure temperature in degrees Celsius and pressure in millibars

- GPS Methods
  - Measure HI in meters
  - Measure temperature in °C
  - Measure pressure in mb
  - Report coordinates in NAD '83 (1992)
  - Prepare obstruction diagrams in meters
    descriptions (to reach) in meters and miles
  - Measure references in meters to surrounding features

TMOSS Surveys

- Measure distances in meters

- Offset mode will require experimentation

- Coordinate made

- PICS upgrade is available to handle conversion

ROW Surveys

- Measure section corner references in meters

- Descriptions of caps and monuments in meters and feet. Still use inches and feet so original records can match new descriptions

- Measure in meters on property lines

Vertical Control

- Use Leica NA2002 levels for control elevations

- Use NAVD '88 (1992) elevations

Right-of-Way

- A Right-of-Way minimum of 20 m for local roads and from thereon in 10 m increments is normally recommended. In restricted circumstances 5 m increments or less will be permissible.
- Standard right of way widths between the proposed right of way lines shall be rounded to the nearest 10 meters. In some instances, in urban areas, the widths may be given to the nearest 5 meters.

Contour Intervals

- Utilize either 10, 5, or 2 meters as contour intervals, dependent on site slope.

Elevations

- Elevation measurements shall be given in meters. Benchmark elevations should be converted from feet to meters.

Examples

Benchmark is 314.15 feet.
Convert to 95.753

Sample Top of Curb	TC 305.224
Sample Bottom of Curb	BC 305.024

Sample Contour Lines:

---------- 106.000 ----------
---------- 105.500 ----------

Contour lines have also been seen on foreign drawings in meters, such as 106, 106.5, 107, etc. This system may also be used.

DESIGN/PLAN PREPARATION

- All Right-of-Way and Construction Plans shall be drawn to metric scales:
  Plan sheets: 1:1000 (rural) **[Use 1 m = 1000 m, not 1 cm = 10 m]**
  1:500 (urban)
  Ownership maps: 1:5000

- All Engineering Design shall be converted to metric units including the definition of the degree of curve from the 100 foot arc definition to the radius definition.

The legal descriptions shall be written as follows:

- Angular measurement shall continue to be made in degrees, minutes, and seconds.

- Surveyed distances shall be given in meters.

- Deed distances shall be given in parenthesis in the units they were recorded.

- Areas shall be given in both conventions. In urban locations, square meters shall be used with the square footage given in parenthesis. In rural locations, hectares shall be used with acres given in parenthesis.

- All Right-of-Way plan tabulation of properties sheets shall give both English and metric units of area in tabular form.

- Right-of-Way professionals shall reserve the right to redraft any drawings in English units for the purpose of public presentations and/or court proceedings.

UTILITIES

ACQUISITION

- All appraisal reports shall be done using the units of measurement in which the surveys were recorded. In the conclusion of value, the cost per unit area shall be shown in both metric and English units.
- All Fair Market Value reports shall report the cost per unit area in both the metric and English units.
- Acquisition and relocation agents shall report the cost per unit area to the property owner in both the metric and English units.

CHAPTER THREE

Roadway Design

The AASHTO Task Force on Geometric Design has reviewed the *Policy on Geometric Design of Highways and Streets* (the "Green Book"), identified nine areas critical to basic geometric design, and submitted initial recommendations addressing metrication items in Geometric Design to the AASHTO Standing Committee on Highways. The committee's recommendations have since been approved by AASHTO.

These values can be used by CDOT as interim design criteria until a complete version of *A Policy on Geometric Design of Highways and Streets* (the "Green Book") is published in 1995.

DRAWING SIZES

The ISO "A" series drawing sizes are preferred metric sizes for design drawings. There are five "A" series sizes:

ISO Designation	Metric Sheet Size	Replaces
A0	841 x 1189 mm	34 x 44 inches
A1	594 x 841 mm	22 x 34 inches
A2	420 x 594 mm	17 x 22 inches
A3	297 x 420 mm	11 x 17 inches
A4	210 x 297 mm	8½ x 11 inches

Sheet size "A0" is the base drawing size with an area of one square meter. Smaller sizes are obtained by halving the long dimension of the previous size. All "A" sizes have a height to width ratio of one to the square root of two.

All full-sized plan sheets should conform to the "A1" metric series size. Drawing borders of 17 mm will be used at the top and bottom and 6 mm at the right edge. The left border (binding edge) will be 45 mm. Until the 841 mm metric paper roll width is commonly available we will continue to use the 36" wide paper. The 2.9" excess width should be added to the left (binding edge) border.

DRAWING SCALES

Metric drawing scales are expressed in nondimensional ratios. Nine scales are preferred: 1:1 (full size), 1:5, 1:10, 1:20, 1:50, 1:100, 1:200, 1:500, and 1:1000. Three others have limited usage: 1:2, 1:25, and 1:250.

Metric Scales		Inch-Foot Scales	Percent Enlargement or Reduction Using Metric Scale
Preferred	Other		
1:1		Full size	No change
	1:2	Half size	No change
1:5		1" = ¼' 1" = ⅓'	-40% -20%
1:10		1" = 1'	+20%
1:20		1" = 2'	+20%
	1:25	1" = 2'	-4%
1:50		1" = 5'	+20%
1:100		1" = 10'	+20%
1:200		1" = 20'	+20%
	1:250	1" = 20'	-4%
1:500		1" = 30' 1" = 40' 1" = 50'	-28% -4% +20%
1:1000		1" = 60' 1" = 100'	-28% +20%

UNITS USED ON DRAWINGS

- Use only one unit of measure on a drawing. Except for large scale site or cartographic drawings, the unit should be the millimeter (mm).
- Omit unit symbols but provide an explanatory note ("All dimensions are shown in millimeters" or "All dimensions are shown in meters").
- Whole numbers always indicate millimeters; decimal numbers taken to three places always indicate meters.
- Where modules are used, the recommended basic module is 100 mm, which is similar to the 4-inch module used in building construction (4 inches = 101.6 mm).

ELEVATION AND CONTOUR INTERVALS

Benchmark elevations will be directly converted from feet to meters. For example, a benchmark elevation of 639.28 feet will be converted directly to 194.583 meters (639.28 ft. ÷ 3.28084 ft./m = 194.583 m). Benchmark elevations should be shown to a 0.001 meter accuracy.

When contours are shown on Bridge Layout sheets and other drawings, the contour interval will be 0.2 meters. Each fifth contour representing an even meter elevation (202.0, 203.0, etc.) will be emphasized and annotated. Intermediate 0.2 meter contours will not be annotated unless they represent a high or low contour on the ground surface that cannot be determined by interpolations between adjacent full meter contours.

A 0.2 meter contour interval is equivalent to about 8 inches. This will result in more tightly packed contour lines than have been generated in the past. In rugged terrain or on steep slopes the contour density may interfere with readability. When this occurs, the 0.2 meter contours should be removed from the densely packed areas only. The even meter contours are to be retained in these areas.

Metric Interval	Inch-Pound Interval
0.2 m	1 ft.
0.5 m	2 ft.
1 m	5 ft.
5 m	10 ft.

STATIONING AND CROSS-SECTION INTERVALS

A station concept based on 1 km (1+000.00) will be used for metric plans. For example, Station 12+273.96 indicates a point 273.96 m forward of kilometer Station 12+000.

Use an equivalent conversion from English to metric when re-establishing points from a previously run survey. For example, P.I. Station 456+35 from a 1965 survey using English units would be defined as kilometer Station 13+909.548 (45,635 ft. ÷ 3280.84 ft./km = 13.909 548 km) in a metric survey. The kilometer stationing on new alignments is arbitrary.

Standard cross-section intervals of 20 meters should be used where alignment is maintained over existing embankments and through rolling terrain. Although 20 meters should be considered the standard, a larger interval may be considered when uniform templates are used over flat terrain. Additional cross-sections should be provided to reflect abrupt changes in either the template or the existing ground.

The usual horizontal and vertical cross-section scale is 1:100 [Use 1 m = 100 m]

ANGLES AND HORIZONTAL CURVES

Angular measurement will continue to be expressed in Degrees, Minutes, and Seconds.

Radius definition of curves, with the radius expressed in meters, will be used rather than Degree of Curve as we currently use.

For example, a 3 degree horizontal curve on ***new alignment*** (Radius = 1909.86 ft. or 582.125 meters) should be referred to as a 580 meter radius curve. Metric radius on ***paper relocated*** horizontal curves should always be expressed in multiples of 5 meter increments.

On the other hand, alignments which incorporate a previously defined horizontal curve should continue to express the radius to the closest 0.001 meter. If the 3 degree curve noted above is a re-creation of a previously established curve, it should be assigned a 582.125 meter radius.

Listed below are three cases defining horizontal curves. In all three cases the curve starts at P.C. Station 300+59.41 (English), equivalent to P.C. Station 9+162.108 (metric).

Case A: Normal English curve definition.

Case B: Metric definition assuming that Case A curve data defined the roadway centerline from a previous survey and is to be retained. All curve data is a direct conversion from English to metric.

Case C: Metric definition of a paper relocation starting at P.C. Station 9+162.108 having approximately the same curvature as the Case A curve. Note that the radius is given in a 5 meter increment.

Case A	Case B	Case C
P.I. Sta. = 302+68.57	P.I. Sta. = 9+225.860	P.I. Sta. = 9+225.628
Δ = 12° 30'	Δ = 12° 30'	Δ = 12° 30'
D = 3° 00'	R = 582.125 m	R = 580.000 m
T = 209.16'	T = 63.752 m	T = 63.520 m
L = 416.67'	L = 127.001 m	L = 126.535 m

Circular Curves

The following table gives minimum rounded radii in meters for limiting values of superelevations for various design speeds.

Design Speed (km/h)	Minimum rounded radius in meters	
	6% maximum superelevation	8% maximum superelevation
40	55	50
50	90	80
60	135	125
70	195	175
80	250	230
90	335	305
100	435	395
110	560	500
120	755	665
130	800	700
140	1000	850

Spiral Curves:

Based on the radius definition of the curve, spiral parameter 'A' is defined as:

$$A^2 = R \times L_3$$

where: A = rate of change of length per unit curvature of spiral
R = radius of circular curve in meters
L_3 = total length of the spiral curve in meters.

ANGLES AND HORIZONTAL CURVES (Cont'd)

Highway Curve Conversion Table for Various Metric Scales

Degree of Curve (100' Arc) D.M.S.	True Radius		Actual Radius @		Represented Radius @			
	(m)	(ft.)	1"=100' (mm)	1"=100' (in.)	1:1000 (m)	1:500 (m)	1:250 (m)	1:200 (m)
0° 15'	6,985.52	22,918.32	5,821.26	229.18	5,821.26	2,910.63	1,455.32	1,164.25
0° 30'	3,492.76	11,459.16	2,910.63	114.59	2,910.63	1,455.32	727.66	582.13
0° 45'	2,328.51	7,639.44	1,940.42	76.39	1,940.42	970.21	485.11	388.08
1° 0'	1,746.38	5,729.58	1,455.32	57.30	1,455.32	727.66	363.83	291.06
1° 15'	1,397.10	4,583.66	1,164.25	45.84	1,164.25	582.13	291.06	232.85
1° 30'	1,164.25	3,819.72	970.21	38.20	970.21	485.11	242.55	194.04
1° 45'	997.93	3,274.05	831.61	32.74	831.61	415.80	207.90	166.32
2° 0'	873.19	2,864.79	727.66	28.65	727.66	363.83	181.91	145.53
2° 15'	776.17	2,546.48	646.81	25.46	646.81	323.40	161.70	129.36
2° 30'	698.55	2,291.83	582.13	22.92	582.13	291.06	145.53	116.43
2° 45'	635.05	2,083.48	529.21	20.83	529.21	264.60	132.30	105.84
3° 0'	582.13	1,909.86	485.11	19.10	485.11	242.55	121.88	97.02
3° 15'	537.35	1,762.95	447.79	17.63	447.79	223.89	111.95	89.56
3° 30'	498.97	1,637.02	415.80	16.37	415.80	207.90	103.95	83.16
3° 45'	465.70	1,527.89	388.08	15.28	388.08	194.04	97.02	77.62
4° 0'	436.59	1,432.40	363.83	14.32	363.83	181.91	90.96	72.77
4° 15'	410.91	1,384.14	342.43	13.48	342.43	171.21	85.61	68.49
4° 30'	388.08	1,273.24	323.40	12.73	323.40	161.70	80.85	64.68
4° 45'	367.66	1,206.23	306.38	12.06	306.38	153.19	76.60	61.28
5° 0'	349.28	1,145.92	291.06	11.46	291.06	145.53	72.77	58.21
5° 15'	332.64	1,092.35	277.20	10.91	277.20	138.60	69.30	55.44
5° 30'	317.52	1,041.74	264.60	10.42	264.60	132.30	66.15	52.92
5° 45'	303.72	996.45	253.10	9.96	253.10	126.55	63.27	50.62
6° 0'	291.06	954.93	242.55	9.55	242.55	121.88	60.64	48.51
6° 15'	279.42	916.73	232.85	9.17	232.85	116.43	58.21	46.57
6° 30'	268.67	881.47	223.89	8.81	223.89	111.95	55.97	44.78
6° 45'	258.72	848.83	215.60	8.49	215.60	107.80	53.90	43.12
7° 0'	249.48	818.51	207.90	8.19	207.90	103.95	51.98	41.58
7° 15'	240.88	790.29	200.73	7.90	200.73	100.37	50.18	40.15
7° 30'	232.85	763.94	194.04	7.64	194.04	97.02	48.51	38.81
7° 45'	225.34	739.30	187.78	7.39	187.78	93.89	46.95	37.56
8° 0'	218.30	716.20	181.91	7.16	181.91	90.96	45.48	36.38
8° 15'	211.68	694.49	176.40	6.94	176.40	88.20	44.10	35.28
8° 30'	205.46	674.07	171.21	6.74	171.21	85.61	42.80	34.24
8° 45'	199.59	654.81	166.32	6.55	166.32	83.16	41.58	33.26
9° 0'	194.04	636.62	161.70	6.37	161.70	80.85	40.43	32.34
9° 15'	188.80	619.41	157.33	6.19	157.33	78.67	39.33	31.47
9° 30'	183.83	603.11	153.19	6.03	153.19	76.60	38.30	30.64
9° 45'	179.12	587.65	149.26	5.88	149.26	74.63	37.32	29.85
10° 0'	174.64	572.96	145.53	5.73	145.53	72.77	36.38	29.11
10° 30'	166.32	545.67	138.60	5.46	138.60	69.30	34.65	27.72
11° 0'	158.76	520.87	132.30	5.21	132.30	66.15	33.08	26.46
11° 30'	151.86	498.22	126.55	4.98	126.55	63.27	31.64	25.31
12° 0'	145.53	477.47	121.28	4.77	121.88	60.64	30.32	24.26
12° 30'	139.71	458.37	116.43	4.58	116.43	58.21	29.11	23.29
13° 0'	134.34	440.74	111.95	4.41	111.95	55.97	27.99	22.39
13° 30'	129.36	424.41	107.80	4.24	107.80	53.90	26.95	21.56
14° 0'	124.74	409.26	103.95	4.09	103.95	51.98	25.99	20.79
14° 30'	120.44	395.14	100.37	3.95	100.37	50.18	25.09	20.07
15° 0'	116.43	381.97	97.02	3.82	97.02	48.51	24.26	19.40
16° 0'	109.15	358.10	90.96	3.58	90.96	45.48	22.74	18.19
17° 0'	102.73	337.03	85.61	3.37	85.61	42.80	21.40	17.12
18° 0'	97.02	318.31	80.85	3.18	80.85	40.43	20.21	16.17
19° 0'	91.91	301.56	76.60	3.02	76.60	38.30	19.15	15.32

Radius Guide Conversion Table for Various Metric Scales

Labelled Radius	Represented Radius @				
@ 1"=100' (ft.)	1:1000 (m)	1:500 (m)	1:250 (m)	1:200 (m)	1:100 (m)
50.00	12.70	6.35	3.18	2.54	1.27
60.00	15.24	7.62	3.81	3.05	1.52
75.00	19.05	9.53	4.76	3.81	1.91
90.00	22.86	11.43	5.72	4.57	2.29
100.00	25.40	12.70	6.35	5.08	2.54
110.00	27.94	13.97	6.99	5.59	2.79
125.00	31.75	15.88	7.94	6.35	3.18
140.00	35.56	17.78	8.89	7.11	3.56
150.00	38.10	19.05	9.53	7.62	3.81
160.00	40.64	20.32	10.16	8.13	4.06
175.00	44.45	22.23	11.11	8.89	4.45
190.00	48.26	24.13	12.07	9.65	4.83
200.00	50.80	25.40	12.70	10.16	5.08
210.00	53.34	26.67	13.34	10.67	5.33
225.00	57.15	28.58	14.29	11.43	5.72
240.00	60.96	30.48	15.24	12.19	6.10
250.00	63.50	31.75	15.88	12.70	6.35
260.00	66.04	33.02	16.51	13.21	6.60
275.00	69.85	34.93	17.46	13.97	6.99
290.00	73.66	36.83	18.42	14.73	7.37
300.00	76.20	38.10	19.05	15.24	7.62
310.00	78.74	39.37	19.69	15.75	7.87
325.00	82.55	41.28	20.64	16.51	8.26
340.00	86.36	43.18	21.59	17.27	8.64
350.00	88.90	44.45	22.23	17.78	8.89
375.00	95.25	47.63	23.81	19.05	9.53

SURVEY PLOTTING ACCURACY

As a frame of reference, distances expressed in metric units will have the following accuracy in English units:

- Closest 0.1 meters will be within 2" of the true distance.
- Closest 0.01 meters will be within 3/16" of the true distance.

With this in mind, survey distances and elevations transferred to plan sheets should be shown as follows:

- Horizontal alignment data (curve information, equations, reference point tie-ins, etc.) and Benchmark elevations should be shown to the closest 0.001 m.
- Roadway elevations, used for pavement tie-ins and vertical clearance computations, should be shown to the closest 0.01 m.
- All horizontal pluses, offsets, physical feature dimensions and locations, etc. should be shown to the closest 0.01 m.

PROPOSED FEATURES ON ROADWAY PLANS

The location of all proposed features should be given in meters or fractional parts of meters to the following accuracy:

- All proposed horizontal alignment data should be given to an accuracy of 0.001 meters.
- Metric curve radii should be in 5 meter increments.
- Vertical profile alignment data should be shown with V.P.I. Stations at even 10 m stations, V.C. Lengths in 20 m increments, and V.P.I. Elevations given to 0.001 m accuracy, where practical.
- All other vertical elevations (breaks in ditch grades, pipe invert elevations, etc.) should be shown to the closest 0.01 meters.
- The location of all proposed features should be shown to the closest one meter, where practical, and never closer than 0.1 meter. The following increments are recommended:

  Drive locations--------------------------Closest 1.0 meters
  Culvert locations------------------------Closest 1.0 meters
  Horizontal ditch grade breaks--------Closest 1.0 meters
  Guard rail limits-----------------------Closest 0.1 meters

PROPOSED FEATURES ON ROADWAY PLANS (Cont'd)

Proprietary items, such as pipe sizes, which do not yet have a standard metric size, should be converted to millimeters using a soft conversion and shown on the plans to the next lower 10 mm increment. This will avoid disputes over the use of material which does not meet the given size if the soft conversion is rounded to the closest 10 mm increment.

For example, proposed pipe sizes should be shown as indicated below:

Metric Pipe Diameter	Inch-Foot Soft Conversion Equivalent	Show As
152 mm	6 in.	150 mm
305 mm	12 in.	300 mm
381 mm	15 in.	375 mm
610 mm	24 in.	600 mm
914 mm	36 in.	900 mm

SPECIFICATIONS

All measurements in construction specifications should be stated in metric. Until existing specification systems are fully converted, the specifier may:

- **Specify metric products** (Check to see if the products to be specified are available in metric sizes).
- **Refer to metric or dual unit codes and standards.** ASHRAE, ASME, and ACI, among others, publish metric editions of some standards. Two of the country's three model code groups (BOCA and SBCCI) as well as ASTM and NFPA publish their documents with dual units (both metric and inch-pound measurements). In addition, most handicapped accessibility standards and a number of product standards are published with dual units. The metric measurements are virtually exact, "soft" numerical conversions that, over time, will be changed through the consensus process into rationalized, rounded "hard" metric dimensions. For now, use the "soft" metric equivalents.
- Convert existing unit measurements to metric (Follow conversion rules on page 1-6).

CROSS SECTION ELEMENTS & DESIGN DATA

The following information is intended to summarize selected design and detailing "equivalent values" as the translation from English to metric units is implemented.

Design Speed

Metric Value (km/h)	English Equivalent (mph)	Running Speed (km/h)
30 (18.64 mph)	20	30
40 (24.83 mph)	25	40
50 (31.07 mph)	30	47
60 (37.28 mph)	35 & 40	55
70 (43.50 mph)	45	63
80 (49.71 mph)	50	70
90 (55.92 mph)	55	77
100 (62.14 mph)	60	85
105 (65.25 mph)	65	85
110 (68.35 mph)	70	91
120 (74.56 mph)	75	98

Shoulders

Metric Value (m)	English Equivalent (ft.)
0.6 (1.97 ft)	2
1.2 (3.94 ft)	4
1.8 (5.91 ft)	6
2.4 (7.87 ft)	8
3.0 (9.84 ft)	10

The Task Force, in establishing shoulder width values, attempted to recognize the value of a shoulder width less than 1 m and provide flexibility for that instance. Always maintain lane and shoulder widths in 0.1 meter increments.

Lane Width

The values established by the AASHTO Task Force on Geometric Design are slightly narrower (ranging from 4 to 10 percent less) than the corresponding Canadian values. Canadian values are set in 0.25 increments. This level of preciseness (hundredths of a meter) appears to be excessive for this element. The Task Force believes that preciseness to 1/10 m is acceptable and has set values accordingly.

Metric Value (m)	English Equivalent (ft.)	Comparison
2.7 (8.86 ft)	9	(1.56% less than 9 ft. lane)
3.0 (9.84 ft)	10	(1.60% less than 10 ft. lane)
3.3 (10.83 ft)	11	(1.55% less than 11 ft. lane)
3.6 (11.81 ft)	12	(1.58% less than 12 ft. lane)

The Task Force believes that the values established are in line with recent research regarding lane widths and safety benefits (reports TRB 214 and NCHRP 15-12 - the latter currently in progress). Furthermore, construction practices and the pavement striping process generally yield lane widths somewhat less than 9, 10, 11, or 12 ft. The metric values established are typically 1.5 percent below the corresponding English values now specified. This difference is considered negligible with respect to safety benefits. Some capacity reduction may theoretically result, but in practical terms, such a reduction is not expected to be significant.

Vertical Clearance

Metric Value (m)	English Equivalent (ft.)
3.8 (12.47 ft)	12
4.3 (14.11 ft)	14
4.9 (16.08 ft)	16

The 4.9 m value is seen to be the critical value since the federal legislation required Interstate design to have 16 ft. vertical clearance. In view of the fact that the Interstate, now virtually complete, is based on this minimum clearance, the metric value should provide this clearance as a minimum. The 4.9 m value accomplishes this objective. Other vertical clearance values are not deemed to be as rigid as this value.

Guard Rail Dimensions

The offset from the face of guard rail to the shoulder break (formerly 3'-3") will now be 1.0 meters.

Barrier Supports Spacing

Metric Value (m)	English Equivalent (ft.)
2	6.56
4	13.12
8	26.25

The value established by the Task Force is approximately 5% more than the current spacing of roadside barriers, but facilitate easy understanding by the highway design engineer and will establish improved acceptance of the conversion to SI units. The value can be either shown in meters or millimeters (4.0 m or 4000 mm) as an example.

This dimension will not involve a change in the currently accepted barriers meeting performance criteria. Industry will be required to provide minor retooling to meet the new lengths of this change. The cost should be minimal and is not expected to increase the overall construction cost of the project.

Clear Zone

With two exceptions, the *Green Book* refers to the *Roadside Design Guide* for clear zone values. The two critical values are the clear zone for urban conditions and locals and collectors. The Task Force has set the following:

	Metric Value (m)
Urban Conditions	0.5 (1.64 ft)
Locals/Collectors	3.0 minimum (9.84 ft)

Curbs

Curb Type	Metric Height (mm)	English Equivalent (in.)
Mountable Curb	150 (max)	6
Barrier Curb	225 (max)	9

The definition of high speed/low speed has an impact on where curb is used.

- Low speed: 60 km/h or less design speed
- High speed: 80 km/h or more design speed

Deflection

Theoretical soft conversions will be made to the nearest 0.05 meter conforming to replacement of NCHRP-230 (scheduled to be 350).

Sight Distance

Stopping Sight Distance	Metric Value (mm)	English Equivalent (ft.)
Eye Height	1070	3.51
Object Height	150	0.5
Headlight Height	610	2

Passing Sight Distance	Metric Value (mm)	English Equivalent (ft.)
Eye Height	1070	3.51
Object Height	1300	4.27

Sight Distance (Cont'd)

Provided are tables III-1, III-6, III-40, and III-42, which were prepared to show various suggested sight distance values.

Design Speed (km/h)	Assumed Speed for Condition (km/h)	Brake Reaction		Coefficient of Friction (f)	Braking Distance on Level (m)	Stopping Sight Distance	
		Time (sec)	Distance (m)			Computed (m)	Rounded for Design (m)
30	30-30	2.5	20.8-20.8	0.40	8.8-8.8	29.6-29.6	30-30
40	40-40	2.5	27.8-27.8	0.38	16.6-16.6	44.4-44.4	50-50
50	47-50	2.5	32.6-34.7	0.35	24.8-28.1	57.4-62.8	60-70
60	55-60	2.5	38.2-41.7	0.33	36.1-42.9	74.3-84.6	80-90
70	63-70	2.5	43.7-48.6	0.31	50.4-62.2	94.1-110.8	100-120
80	70-80	2.5	48.6-55.5	0.30	64.2-83.9	112.8-139.4	120-140
90	77-90	2.5	53.5-62.5	0.30	77.7-106.2	131.2-168.7	140-170
100	85-100	2.5	59.0-69.4	0.29	98.0-135.6	157.0-205.0	160-210
110	91-110	2.5	63.2-76.4	0.28	116.3-170.0	179.5-246.4	180-250
120	98-120	2.5	68.0-83.3	0.28	134.9-202.3	202.9-285.6	210-290

Table III-1. Stopping sight distance (wet pavements).

Sight Distance (Cont'd)

Design Speed (km/h)	Maximum e	Maximum f	Total (e+f)	Calculated Radius (meters)	Rounded Radius (meters)
30	0.04	0.17	0.21	33.7	35
40	0.04	0.17	0.21	60.0	60
50	0.04	0.16	0.20	98.4	100
60	0.04	0.15	0.19	149.2	150
70	0.04	0.14	0.18	214.3	215
80	0.04	0.14	0.18	280.0	280
90	0.04	0.13	0.17	375.2	375
100	0.04	0.12	0.16	492.1	490
110	0.04	0.11	0.15	635.2	635
120	0.04	0.09	0.13	872.2	870
30	0.06	0.17	0.23	30.8	30
40	0.06	0.17	0.23	54.8	55
50	0.06	0.16	0.22	89.5	90
60	0.06	0.15	0.21	135.0	135
70	0.06	0.14	0.20	192.9	195
80	0.06	0.14	0.20	252.0	250
90	0.06	0.13	0.19	335.7	335
100	0.06	0.12	0.18	437.4	435
110	0.06	0.11	0.17	560.4	560
120	0.06	0.09	0.15	755.9	755

Table III-6. Minimum radius determined for limiting values of e and f, rural highways and high-speed urban streets.

Sight Distance (Cont'd)

Design Speed (km/h)	Maximum e	Maximum f	Total (e+f)	Calculated Radius (meters)	Rounded Radius (meters)
30	0.08	0.17	0.25	28.3	30
40	0.08	0.17	0.25	50.4	50
50	0.08	0.16	0.24	82.0	80
60	0.08	0.15	0.23	123.2	125
70	0.08	0.14	0.22	175.4	175
80	0.08	0.14	0.22	229.1	230
90	0.08	0.13	0.21	303.7	305
100	0.08	0.12	0.20	393.7	395
110	0.08	0.11	0.19	501.5	500
120	0.08	0.09	0.17	667.0	665
30	0.10	0.17	0.27	26.2	25
40	0.10	0.17	0.27	46.7	45
50	0.10	0.16	0.26	75.7	75
60	0.10	0.15	0.25	113.4	115
70	0.10	0.14	0.24	160.8	160
80	0.10	0.14	0.24	210.0	210
90	0.10	0.13	0.23	277.3	275
100	0.10	0.12	0.22	357.9	360
110	0.10	0.11	0.21	453.7	455
120	0.10	0.09	0.19	596.8	595

Table III-6, continued.

Sight Distance (Cont'd)

Design Speed (km/h)	Maximum e	Maximum f	Total (e+f)	Calculated Radius (meters)	Rounded Radius (meters)
30	0.12	0.17	0.29	24.4	25
40	0.12	0.17	0.29	43.4	45
50	0.12	0.16	0.28	70.3	70
60	0.12	0.15	0.27	105.0	105
70	0.12	0.14	0.26	148.4	150
80	0.12	0.14	0.26	193.8	195
90	0.12	0.13	0.25	255.1	255
100	0.12	0.12	0.24	328.1	330
110	0.12	0.11	0.23	414.2	415
120	0.12	0.09	0.21	539.9	540

Table III-6, continued.

Sight Distance (Cont'd)

Design Speed (km/h)	Assumed Speed for Condition (km/h)	Coefficient of Friction (f)	Stopping Sight Distance Rounded for Design (m)	Rate of Vertical Curvature, K (length (m) per percent of A)	
				Computed[a]	Rounded for Design
30	30-30	0.40	30-30	2.17-2.17	3-3
40	40-40	0.38	50-50	4.88-4.88	5-5
50	47-50	0.35	60-70	8.16-9.76	9-10
60	55-60	0.33	80-90	13.66-17.72	14-18
70	63-70	0.31	100-120	21.92-30.39	22-31
80	70-80	0.30	120-140	31.49-48.10	32-49
90	77-90	0.30	140-170	42.61-70.44	43-71
100	85-100	0.29	160-210	61.01-104.02	62-105
110	91-110	0.28	180-250	79.75-150.28	80-151
120	98-120	0.28	210-290	101.90-201.90	102-202

[a]*Using computed values of stopping sight distance.*

Table III-40. Design controls for crest vertical curves based on stopping sight distance.

Sight Distance (Cont'd)

Design Speed (km/h)	Assumed Speed for Condition (km/h)	Coefficient of Friction (f)	Stopping Sight Distance Rounded for Design (m)	Rate of Vertical Curvature, K (length (m) per percent of A)	
				Computed[a]	Rounded for Design
30	30-30	0.40	30-30	3.88-3.88	4-4
40	40-40	0.38	50-50	7.11-7.11	8-8
50	47-50	0.35	60-70	10.20-11.54	11-12
60	55-60	0.33	80-90	14.45-17.12	15-18
70	63-70	0.31	100-120	19.62-24.08	20-25
80	70-80	0.30	120-140	24.62-31.86	25-32
90	77-90	0.30	140-170	29.62-39.95	30-40
100	85-100	0.29	160-210	36.71-50.06	37-51
110	91-110	0.28	180-250	42.95-61.68	43-62
120	98-120	0.28	210-290	49.47-72.72	50-73

[a]*Using computed values of stopping sight distance.*

Table III-42. Design controls for sag vertical curves based on stopping sight distance.

SUPERELEVATION

Rural Design [e(max) = 0.06 m/m]

(Applies to two lane roadways rotated about centerline and four lane roadways where each two lane set is rotated about the inside edge of traveled way)

		f(max) 0.16 V(R) 47 km/h V(D) 50 km/h				f(max) 0.15 V(R) 55 km/h V(D) 60 km/h				f(max) 0.14 V(R) 63 km/h V(D) 70 km/h				f(max) 0.14 V(R) 70 km/h V(D) 80 km/h			
CURVE		50 km/h				60 km/h				70 km/h				80 km/h			
R	D	e	S	C	T	e	S	C	T	e	S	C	T	e	S	C	T
(m)	(deg)	(m/m)	(m)	(m)	(m)	(m/m)	(m)	(m)	(m)	(m/m)	(m)	(m)	(m)	(m/m)	(m)	(m)	(m)
7000	0.24948	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
5000	0.34928	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
4000	0.43659	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
3500	0.49896	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
3000	0.58213	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
2500	0.69855	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
2250	0.77617	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
2000	0.87319	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	RC	45	45	0.0
1750	0.99793	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	RC	45	45	0.0
1500	1.16425	NC	0	0	0.0	NC	0	0	0.0	RC	40	40	0.0	0.022	45	41	0.1
1250	1.39710	NC	0	0	0.0	RC	35	35	0.0	0.022	40	36	0.1	0.026	45	35	0.1
1000	1.74638	NC	0	0	0.0	0.021	35	33	0.1	0.026	40	31	0.1	0.031	45	29	0.1
900	1.94042	RC	30	30	0.0	0.023	35	30	0.1	0.028	40	29	0.1	0.034	45	26	0.1
800	2.18297	RC	30	30	0.0	0.025	35	28	0.1	0.031	40	26	0.1	0.036	45	25	0.1
700	2.49482	0.021	30	29	0.1	0.028	35	25	0.1	0.034	40	24	0.1	0.040	45	23	0.1
600	2.91063	0.024	30	25	0.1	0.031	35	23	0.1	0.038	40	21	0.1	0.043	45	21	0.1
500	3.49275	0.028	30	21	0.1	0.035	35	20	0.1	0.042	40	19	0.1	0.048	50	21	0.2
400	4.36594	0.033	30	18	0.1	0.040	35	18	0.1	0.047	45	19	0.2	0.053	55	21	0.3
350	4.98965	0.035	30	17	0.1	0.043	40	19	0.2	0.050	50	20	0.3	0.056	60	21	0.4
300	5.82125	0.039	35	18	0.2	0.046	40	17	0.2	0.054	55	20	0.4	0.059	65	22	0.6
280	6.23706	0.040	35	18	0.2	0.048	45	19	0.3	0.055	55	20	0.4	0.060	65	22	0.6
260	6.71683	0.041	35	17	0.2	0.049	45	18	0.3	0.057	55	19	0.5	0.060	65	22	0.7
240	7.27657	0.043	35	16	0.2	0.051	45	18	0.4	0.058	60	21	0.6				
220	7.93807	0.045	40	18	0.3	0.053	50	19	0.5	0.059	60	20	0.7				
200	8.73188	0.047	40	17	0.3	0.055	50	18	0.5	0.060	60	20	0.7				
190	9.19145	0.048	40	17	0.4	0.056	50	18	0.5								
180	9.70209	0.049	40	16	0.4	0.057	50	18	0.6								
170	10.27280	0.050	40	16	0.4	0.058	55	19	0.7								
160	10.91485	0.052	45	17	0.5	0.059	55	19	0.8								
150	11.64251	0.053	45	17	0.6	0.060	55	18	0.8								
140	12.47411	0.054	45	17	0.6	0.060	55	18	0.9								
130	13.43366	0.056	45	16	0.6												
120	14.55313	0.057	50	18	0.9												
110	15.87615	0.058	50	17	0.9												
100	17.46376	0.060	50	17	1.0												
90	19.40418	0.060	50	17	1.2												

D = Degree of Curve (Based on a 30.48 m arc length definition)
e = Superelevation
S = Superelevation Runoff Distance (Spiral Length) i.e. Distance from e = 0.000 to e = design superelevation
C = Crown Runoff Distance i.e. Distance from e = 0.000 to e = NC (0.020)
T = "Spiral Throw Distance" i.e. Lateral offset of curve with a spiral transition vs. standard circular curve
NC = Normal Crown
RC = Reverse Crown

NOTE: Shaded e, S, C, & T values in the table are where spiral transitions are recommended.
Whenever the "throw distance equals or exceeds 0.5 m, the use of spiral transitions are strongly recommended.

SUPERELEVATION (Cont'd)

Rural Design [e(max) = 0.06 m/m]

(Applies to two lane roadways rotated about centerline and four lane roadways where each two lane set is rotated about the inside edge of traveled way)

		f(max) 0.13 V(R) 77 km/h V(D) 90 km/h				f(max) 0.12 V(R) 85 km/h V(D) 100 km/h				f(max) 0.11 V(R) 91 km/h V(D) 110 km/h				f(max) 0.09 V(R) 98 km/h V(D) 120 km/h			
CURVE		90 km/h				100 km/h				110 km/h				120 km/h			
R	D	e	S	C	T	e	S	C	T	e	S	C	T	e	S	C	T
(m)	(deg)	(m/m)	(m)	(m)	(m)	(m/m)	(m)	(m)	(m)	(m/m)	(m)	(m)	(m)	(m/m)	(m)	(m)	(m)
7000	0.24948	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
5000	0.34928	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
4000	0.43659	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	RC	65	65	0.0
3500	0.49896	NC	0	0	0.0	NC	0	0	0.0	RC	60	60	0.0	RC	65	65	0.1
3000	0.58213	NC	0	0	0.0	RC	55	55	0.0	RC	60	60	0.0	0.023	65	57	0.1
2500	0.69855	RC	50	50	0.0	RC	55	55	0.1	0.023	60	52	0.1	0.027	65	48	0.1
2250	0.77617	RC	50	50	0.0	0.022	55	50	0.1	0.026	60	46	0.1	0.030	65	43	0.1
2000	0.87319	0.021	50	48	0.1	0.025	55	44	0.1	0.028	60	43	0.1	0.033	65	39	0.1
1750	0.99793	0.023	50	43	0.1	0.028	55	39	0.1	0.032	60	38	0.1	0.037	65	35	0.1
1500	1.16425	0.027	50	37	0.1	0.031	55	35	0.1	0.036	60	33	0.1	0.042	65	31	0.1
1250	1.39710	0.031	50	32	0.1	0.036	55	31	0.1	0.041	60	29	0.1	0.048	65	27	0.1
1000	1.74638	0.036	50	28	0.1	0.042	55	26	0.1	0.048	65	27	0.2	0.056	80	29	0.3
900	1.94042	0.039	50	26	0.1	0.045	55	24	0.1	0.051	65	25	0.2	0.058	80	28	0.3
800	2.18297	0.042	50	24	0.1	0.049	60	24	0.2	0.054	70	26	0.3	0.060	85	28	0.4
700	2.49482	0.046	55	24	0.2	0.052	65	25	0.3	0.058	75	26	0.3				
600	2.91063	0.050	60	24	0.2	0.056	70	25	0.3	0.060	80	27	0.4				
500	3.49275	0.054	65	24	0.4	0.059	75	25	0.5								
400	4.36594	0.059	70	24	0.5												
350	4.98965	0.060	70	23	0.6												
300	5.82125																
280	6.23706																
260	6.71683																
240	7.27657																
220	7.93807																
200	8.73188																
190	9.19145																
180	9.70209																
170	10.27280																
160	10.91485																
150	11.64251																
140	12.47411																
130	13.43366																
120	14.55313																
110	15.87615																
100	17.46376																
90	19.40418																

D = Degree of Curve (Based on a 30.48 m arc length definition)
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C = Crown Runoff Distance i.e. Distance from e = 0.000 to e = NC (0.020)
T = "Spiral Throw Distance" i.e. Lateral offset of curve with a spiral transition vs. standard circular curve
NC = Normal Crown
RC = Reverse Crown

NOTE: Shaded e, S, C, & T values in the table are where spiral transitions are recommended.
Whenever the "throw distance equals or exceeds 0.5 m, the use of spiral transitions are strongly recommended.

SUPERELEVATION (Cont'd)

Rural Design [e(max) = 0.08 m/m]

(Applies to two lane roadways rotated about centerline and four lane roadways where each two lane set is rotated about the inside edge of traveled way)

		f(max) 0.16 V(R) 47 km/h V(D) 50 km/h				f(max) 0.15 V(R) 55 km/h V(D) 60 km/h				f(max) 0.14 V(R) 63 km/h V(D) 70 km/h				f(max) 0.14 V(R) 70 km/h V(D) 80 km/h			
CURVE		50 km/h				60 km/h				70 km/h				80 km/h			
R	D	e	S	C	T	e	S	C	T	e	S	C	T	e	S	C	T
(m)	(deg)	(m/m)	(m)	(m)	(m)	(m/m)	(m)	(m)	(m)	(m/m)	(m)	(m)	(m)	(m/m)	(m)	(m)	(m)
7000	0.24948	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
5000	0.34928	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
4000	0.43659	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
3500	0.49896	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
3000	0.58213	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
2500	0.69855	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
2250	0.77617	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
2000	0.87319	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	RC	45	45	0.0
1750	0.99793	NC	0	0	0.0	NC	0	0	0.0	RC	40	40	0.0	RC	45	45	0.0
1500	1.16425	NC	0	0	0.0	NC	0	0	0.0	RC	40	40	0.0	0.024	45	38	0.1
1250	1.39710	NC	0	0	0.0	RC	35	35	0.0	0.023	40	35	0.1	0.028	45	32	0.1
1000	1.74638	NC	0	0	0.0	0.022	35	32	0.1	0.028	40	29	0.1	0.034	45	26	0.1
900	1.94042	RC	30	30	0.0	0.024	35	29	0.1	0.031	40	26	0.1	0.037	45	24	0.1
800	2.18297	RC	30	30	0.0	0.027	35	26	0.1	0.034	40	24	0.1	0.041	45	22	0.1
700	2.49482	0.022	30	27	0.1	0.030	35	23	0.1	0.038	40	21	0.1	0.045	50	22	0.1
600	2.91063	0.026	30	23	0.1	0.034	35	21	0.1	0.043	45	21	0.1	0.051	55	22	0.2
500	3.49275	0.030	30	20	0.1	0.039	35	18	0.1	0.049	50	20	0.2	0.058	65	22	0.4
400	4.36594	0.036	30	17	0.1	0.047	45	19	0.2	0.057	55	19	0.3	0.066	70	21	0.5
350	4.98965	0.040	35	18	0.1	0.051	45	18	0.2	0.062	60	19	0.4	0.071	75	21	0.7
300	5.82125	0.045	40	18	0.2	0.056	50	18	0.3	0.067	65	19	0.6	0.076	80	21	0.9
280	6.23706	0.047	40	17	0.2	0.059	55	19	0.4	0.070	70	20	0.7	0.077	85	22	1.1
260	6.71683	0.049	40	16	0.3	0.061	55	18	0.5	0.072	70	19	0.8	0.079	85	22	1.2
240	7.27657	0.052	45	17	0.4	0.064	60	19	0.6	0.075	75	20	1.0	0.080	85	21	1.3
220	7.93807	0.055	45	16	0.4	0.067	60	18	0.7	0.077	75	19	1.1				
200	8.73188	0.058	50	17	0.5	0.070	65	19	0.9	0.079	80	20	1.3				
190	9.19145	0.059	50	17	0.5	0.072	65	18	0.9	0.080	80	20	1.4				
180	9.70209	0.061	50	16	0.6	0.073	65	18	1.0	0.080	80	20	1.5				
170	10.27280	0.063	55	17	0.7	0.075	70	19	1.2								
160	10.91485	0.065	55	17	0.8	0.076	70	18	1.3								
150	11.64251	0.067	55	16	0.8	0.078	70	18	1.4								
140	12.47411	0.069	60	17	1.1	0.079	75	19	1.7								
130	13.43366	0.071	60	17	1.2	0.080	75	19	1.8								
120	14.55313	0.074	60	16	1.2												
110	15.87615	0.076	65	17	1.6												
100	17.46376	0.078	65	17	1.8												
90	19.40418	0.079	65	16	1.9												

D = Degree of Curve (Based on a 30.48 m arc length definition)
e = Superelevation
S = Superelevation Runoff Distance (Spiral Length) i.e. Distance from e = 0.000 to e = design superelevation
C = Crown Runoff Distance i.e. Distance from e = 0.000 to e = NC (0.020)
T = "Spiral Throw Distance" i.e. Lateral offset of curve with a spiral transition vs. standard circular curve
NC = Normal Crown
RC = Reverse Crown

NOTE: Shaded e, S, C, & T values in the table are where spiral transitions are recommended.
Whenever the "throw distance equals or exceeds 0.5 m, the use of spiral transitions are strongly recommended.

SUPERELEVATION (Cont'd)

Rural Design [e(max) = 0.08 m/m]

(Applies to two lane roadways rotated about centerline and four lane roadways where each two lane set is rotated about the inside edge of traveled way)

		f(max) 0.13 V(R) 77 km/h V(D) 90 km/h				f(max) 0.12 V(R) 85 km/h V(D) 100 km/h				f(max) 0.11 V(R) 91 km/h V(D) 110 km/h				f(max) 0.09 V(R) 98 km/h V(D) 120 km/h			
CURVE		90 km/h				100 km/h				110 km/h				120 km/h			
R	D	e	S	C	T	e	S	C	T	e	S	C	T	e	S	C	T
(m)	(deg)	(m/m)	(m)	(m)	(m)	(m/m)	(m)	(m)	(m)	(m/m)	(m)	(m)	(m)	(m/m)	(m)	(m)	(m)
7000	0.24948	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
5000	0.34928	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0
4000	0.43659	NC	0	0	0.0	NC	0	0	0.0	NC	0	0	0.0	RC	65	65	0.0
3500	0.49896	NC	0	0	0.0	NC	0	0	0.0	RC	60	60	0.0	0.021	65	62	0.1
3000	0.58213	NC	0	0	0.0	RC	55	55	0.0	0.021	60	57	0.0	0.024	65	54	0.1
2500	0.69855	RC	50	50	0.0	0.021	55	52	0.1	0.024	60	50	0.1	0.029	65	45	0.1
2250	0.77617	RC	50	50	0.0	0.023	55	48	0.1	0.027	60	44	0.1	0.032	65	41	0.1
2000	0.87319	0.022	50	45	0.1	0.026	55	42	0.1	0.030	60	40	0.1	0.035	65	37	0.1
1750	0.99793	0.025	50	40	0.1	0.030	55	37	0.1	0.034	60	35	0.1	0.040	65	33	0.1
1500	1.16425	0.028	50	36	0.1	0.034	55	32	0.1	0.039	60	31	0.1	0.046	65	28	0.1
1250	1.39710	0.033	50	30	0.1	0.040	55	28	0.1	0.046	60	26	0.1	0.054	75	28	0.2
1000	1.74638	0.040	50	25	0.1	0.048	60	25	0.1	0.055	75	27	0.2	0.065	90	28	0.3
900	1.94042	0.044	50	23	0.1	0.052	65	25	0.2	0.060	80	27	0.3	0.071	100	28	0.5
800	2.18297	0.048	55	23	0.2	0.057	70	25	0.3	0.066	85	26	0.4	0.076	105	28	0.6
700	2.49482	0.053	60	23	0.2	0.063	80	25	0.4	0.072	95	26	0.5	0.080	110	28	0.7
600	2.91063	0.060	70	23	0.3	0.069	85	25	0.5	0.077	100	26	0.7				
500	3.49275	0.067	80	24	0.5	0.076	95	25	0.8								
400	4.36594	0.075	85	23	0.8	0.080	100	25	1.0								
350	4.98965	0.079	90	23	1.0												
300	5.82125																
280	6.23706																
260	6.71683																
240	7.27657																
220	7.93807																
200	8.73188																
190	9.19145																
180	9.70209																
170	10.27280																
160	10.91485																
150	11.64251																
140	12.47411																
130	13.43366																
120	14.55313																
110	15.87615																
100	17.46376																
90	19.40418																

D = Degree of Curve (Based on a 30.48 m arc length definition)
e = Superelevation
S = Superelevation Runoff Distance (Spiral Length) i.e. Distance from e = 0.000 to e = design superelevation
C = Crown Runoff Distance i.e. Distance from e = 0.000 to e = NC (0.020)
T = "Spiral Throw Distance" i.e. Lateral offset of curve with a spiral transition vs. standard circular curve
NC = Normal Crown
RC = Reverse Crown

NOTE: Shaded e, S, C, & T values in the table are where spiral transitions are recommended.
Whenever the "throw distance equals or exceeds 0.5 m, the use of spiral transitions are strongly recommended.

HYDRAULICS

Pipe/Conduit

Pipe is one of the most ubiquitous products in construction. It is made of a wide variety of materials, including galvanized steel, black steel, copper, cast iron, concrete, and various plastics such as ABS, PVC, CPVC, polyethylene, and polybutylene, among others.

Few, if any, pipe products have actual dimensions that are in even, round inch-pound numbers, so there is no need to convert them to even, round metric numbers. Here are the inch-pound names for pipe products (NPS or "nominal pipe size") and their metric equivalents (DN or "diameter nominal"). The metric names conform to International Standards Organization (ISO) usage and apply to all plumbing, natural gas, heating oil, drainage, and miscellaneous piping used in buildings and civil works projects. For pipe over 60 inches, use 1 in. = 25 mm.

Nominal Sizes	
DN (mm)	**NPS (in.)**
6	1/8
7	3/16
8	1/4
10	3/8
15	1/2
18	5/8
20	3/4
25	1
32	1¼
40	1½
50	2
65	2½
80	3
90	3½
100	4
115	4½
125	5

Table of Nominal Pipe Sizes in Inches and Millimeters

Pipe/Conduit (Cont'd)

Nominal Sizes	
DN (mm)	NPS (in.)
150	6
200	8
250	10
300	12
375	15
450	18
525	21
600	24
750	30
900	36
1050	42
1200	48
1350	54
1500	60
1650	66
1800	72
1950	78
2100	84
2250	90
2400	96
2550	102
2700	108
2850	114
3000	120

Table of Nominal Pipe Sizes in Inches and Millimeters (Cont'd)

Pipe/Conduit (Cont'd)

Pipe Thickness			
AASHTO SI (mm)	English Value (in.)	Nominal Rounded Up (mm)	Rounded Down (mm)
1.02	0.040	1.1 (0.04331)	1.0 (0.03937)
1.32	0.052	1.4 (0.05512)	1.3 (0.05118)
1.63	0.064	1.65 (0.06496)	1.6 (0.06299)
2.01	0.079	2.1 (0.08268)	2.0 (0.07874)
2.77	0.109	2.8 (0.11024)	2.7 (0.1063)
3.51	0.138	3.6 (0.14173)	3.5 (0.13780)
4.27	0.168	4.3 (0.16929)	4.2 (0.16535)

Pipe Thickness			
AASHTO SI (mm)	English Value (in.)	Minimum Rounded Up (mm)	Rounded Down (mm)
0.91	0.036	1.0 (0.03931)	0.9 (0.03543)
1.17	0.046	1.2 (0.04724)	1.1 (0.04331)
1.45	0.057	1.5 (0.05906)	1.4 (0.05512)
1.83	0.072	1.9 (0.07480)	1.8 (0.07087)
2.57	0.101	2.6 (0.10236)	2.5 (0.09843)
3.28	0.129	3.3 (0.12992)	3.2 (0.12598)
4.04	0.159	4.1 (0.16142)	4.0 (0.15748)

Pipe/Conduit (Cont'd)

Pipe Corrugation Size		
AASHTO SI (mm)		English Equivalent (in.)
68 x 13	(2.68 in. x .512 in.)	2⅔ x ½
76 x 25	(2.99 in. x .984 in.)	3 x 1
125 x 25	(4.921 in. x .984 in.)	5 x 1
19 x 19 x 190	(.748 in. x .748 in. x 7.48 in.)	¾ x ¾ x 7½
19 x 25 x 292	(.748 in. x .984 in. x 11.496 in.)	¾ x 1 x 11½

Pipe Lengths		
Metric Value (m)	English Equivalent (ft.)	Show As (m)
2.4384	8	2.5 (8.2 ft.)
3.0480	10	3.0 (9.8 ft.)
4.8768	16	5.0 (16.4 ft.)
6.0960	20	6.0 (19.7 ft.)
7.3152	24	7.5 (24.6 ft.)
9.1440	30	9.0 (29.5 ft.)

Pipe/Conduit (Cont'd)

Metric Value			English Value	
Designated Size (Diameter of Pipe) (mm)	Permissible Variation Internal Pipe Diameter		Pipe Diameter	
	Min., mm	Max., mm	in.	mm
100	100	110	4	101.6
150	150	160	6	152.4
200	200	210	8	203.2
250	250	260	10	254.0
300	300	310	12	304.8
375	375	390	15	381.0
450	450	465	18	457.2
525	525	545	21	533.4
600	600	620	24	609.6
675	675	695	27	685.8
750	750	775	30	762.0
825	825	850	33	838.2
900	900	925	36	914.4
1050	1050	1080	42	1066.8
1200	1200	1230	48	1219.2
1350	1350	1385	54	1371.6
1500	1500	1540	60	1524.0
1650	1650	1695	66	1676.4
1800	1800	1850	72	1828.8
1950	1950	2000	78	1981.2
2100	2100	2155	84	2133.6
2250	2250	2310	90	2286.0

Table of Designated Pipe Sizes for Circular Concrete Pipe in Inches and Millimeters

Pipe/Conduit (Cont'd)

Metric Value			English Value	
Designated Size (Diameter of Pipe) (mm)	Permissible Variation Internal Pipe Diameter		Pipe Diameter	
	Min., mm	Max., mm	in.	mm
2400	2400	2465	96	2438.4
2550	2550	2620	102	2590.8
2700	2700	2770	108	2743.2
2850	2850	2925	114	2895.6
3000	3000	3080	120	3048.0
3150	3150	3235	126	3200.4
3300	3300	3390	132	3352.8
3450	3450	3540	138	3505.2
3600	3600	3695	144	3657.6

Table of Designated Pipe Sizes for Circular Concrete Pipe in Inches and Millimeters (Cont'd)

COST ESTIMATION

BAMS Proposal and Estimates System (PES) and Letting and Award System (LAS)

Converting from the currently used system of units to the metric system will present a few minor issues for the BAMS PES and LAS modules:

- A new items list with a new spec year is being created. It will contain all existing items with changes for metric dimensions and metric units of measure.
- There will have to be an investigation of the impact on the system of having two lists of items with the same item numbers and two different units of measure.
- Two versions of the Code Book and Cost Data Book will have to be maintained during the transitional period (Metric Code Books are currently available from the Cost Estimates Unit).
- There will have to be a decision about whether to convert the old estimate data over to the metric system.

The rest of the activities in the PES and LAS modules will not be affected. There is no impact on the bid letting and award process for CDOT. The contractors will be forced to submit bids with item quantities in metrics, but otherwise, there will be no changes in this area.

The brunt of the impact of this conversion will be felt by the Bid Monitoring Unit. The major issue for BAMS concerns the conversion of existing data or future data for the DSS module. Since this module relies heavily on historical data, AASHTO will need to address how the conversion is to be handled (which factors will be used, etc.). Attached to a letter dated January 31, 1992, was AASHTO's matrix entitled "Status of Metrication Within AASHTOWare Products". The portion of the report dealing with BAMS said, "No scheduled or planned work to include metric at this time in any modules. Because some modules use historic files, if metric is added, development of a conversion process will be essential."

The operation of the CES module will also be affected, as the historical data base derived from the PEMETH model of DSS will be adversely affected by the change to metric.

CHAPTER FOUR

Structures

The following standards shall be used in the conversion of Staff Bridge activities to the metric system.

- Long Bridges will be those over 60 m in length.

- The bridge design detail and rating manuals shall be converted to metric units not later than December 31, 1995. All plans and specifications prepared within the Branch and to be included in PS & E packages advertised after September 30, 1996, will be in metric units. Advertising dates shall be obtained from Regional Preconstruction Engineers.

- All inspection reports shall be reported in metric units beginning January 1, 1995. No conversion is necessary for reports prior to that date; however, a metric conversion table shall be included in each structure folder beginning January 1, 1995, to facilitate comparative dimensions.

- Formula conversions contained with the current AASHTO Standard Specifications for Highway Bridges and Structures, Fifteenth Edition, Appendix E, Metric Equivalents of U.S. Customary Units shall be used in computations. These conversions represent a soft conversion of all formulas within the specifications. Information Systems will be requested to prepare our computer programs for metric computations. Computer programs not within the control of CDOT will hopefully be converted by the manager of the programs. Such programs include BDS, PONTIS, SAP90, BRASS, etc.

- Conversions of all prefabricated elements shall be made on a soft conversion basis unless and until industry modifies the dimensions of current products, such as Colorado G54 girders, structural members (e.g. 12BP53), etc.

- All equipment purchased after January 1, 1995, shall be capable of displaying metric units. This does not preclude purchasing equipment capable of displaying metric units prior to that date as new or replacement equipment.

- Structural calculations should be done in metric, but for computer programs and/or other information not available in metric, soft conversion is acceptable to complete projects.

- Since no international trend exists on standardization of steel shapes, metric projects shall use the same steel shapes currently used, only use the metric dimensions listed in ASTM A6/A6M. A6/A6M lists both inch and mm dimensions of the shapes. All LRFD property, shape, and specification design data is available in metric from AISC for A6/A6M steel shapes (Phone Orders: AISC, Chicago, IL, (312) 670-5414).

DRAWING SIZES

The following represents the numerical conversion of standard engineering paper and drawing sizes which shall be used:

ISO Designation	Metric Sheet Size	Replaces
A1	841 x 594 mm	22 x 34 inches
A3	297 x 420 mm	11 x 17 inches
A4	210 x 297 mm	8½ x 11 inches

All full-sized plan sheets should conform to the "Al" metric series size. Drawing borders of 17 mm will be used at the top and bottom and 6 mm at the right edge. The left border (binding edge) will be 45 mm. Until the 841 mm metric paper roll width is commonly available we will continue to use the 36" wide paper. The 2.9" excess width should be added to the left (binding edge) border.

DRAWING SCALES

AIA preferred metric scales, all multiples of 1, 2, or 5 shall be used in preparation of metric scaled engineering drawings:

Metric Scales	Architectural
1:2	1:2
1:5	3" = 1'
1:10	1½" = 1' 1" = 1'
1:20	¾" = 1' ½" = 1'
1:50	¼" = 1'
1:100	⅛" = 1'
1:200	1/16" = 1' 1" = 20'
1:500	1/32" = 1' 1" = 40' 1" = 50'
1:1000	1" = 80' 1" = 100'

FASTENERS

- Large projects shall use ASTM A325 and A490 metric bolts.
- There are 7 standard metric bolt sizes, which replace the 9 bolts currently used. They are: 16, 20, 22, 24, 27, 30, and 36 mm.
- Minimum order quantities may apply, so small metric projects should verify availability during design.

UNITS USED ON DRAWINGS

- SI drawings shall use mm exclusively.
- So that it is not necessary to write "mm" after each dimension, each drawing should have the following note on it: "ALL DIMENSIONS ARE MILLIMETERS (mm) UNLESS OTHERWISE NOTED".
- SI drawings should almost never show decimal millimeters (e.g. 2034.5), unless a high precision part or product thickness is being detailed. Use whole mm (e.g. 2035).
- Dual dimensions shall not be used on SI drawings.
- Shop drawings shall be submitted using mm only.

Other metric units to be used within the Branch include:

- The kilogram (kg) is the base unit for mass.
- The newton (N) is the derived unit of force (mass x acceleration $\equiv$ ($kg \cdot m/s^2$)).
- The Pascal (Pa) is the unit of pressure and stress ($Pa = N/m^2$).
- Structural calculations shall be shown in MPa or kPa.
- Loads shall be specified in kilopascals (kPa).
- Plane angles will continue to be designated in degrees (degrees, minutes, and seconds).
- Slope is expressed in non-dimensional ratios. The horizontal component is shown first and then the vertical. For instance, a rise of one meter in four meters is expressed as 4:1. The units that are compared should be the same (meters to meters, millimeters to millimeters, etc.).
- The table on page 1-10 (Civil and Structural Engineering Conversion Factors) contains the engineering conversion factors which shall be used by all personnel of the Branch.

UNITS USED ON DRAWINGS (Cont'd)

The following tables represent the soft conversion metric equivalents of U.S. Customary Units as contained within the Fifteenth Edition of AASHTO. Unless and until the expressions within AASHTO are revised to hard conversions, these conversions shall be used:

Length	
Metric Value (mm)	**U.S. Equivalent (in.)**
2	1/16
3	0.12
6	0.23
6	1/4
10	3/8
11	0.43
13	1/2
19	3/4
20	0.80
25	1
51	2
76	3
152	6
203	8
229	9
254	10
305	12
Metric Value (m)	**U.S. Equivalent (ft.)**
0.915	3
3.048	10
12.192	40
243.840	800

UNITS USED ON DRAWINGS (Cont'd)

Load	
Metric Value	**U.S. Equivalent**
2669 N	600 lb.
3558 N	800 lb.
4537 N	1020 lb.
5604 N	1260 lb.
6761 N	1520 lb.
7962 N	1790 lb.
9341 N	2100 lb.
10,764 N	2420 lb.
12,321 N	2770 lb.
44.48 kN	10,000 lb.
108 kN	24,000 lb.
142 kN	16 Tons
178 kN	20 Tons
445 kN	50 Tons
74.45 kg/m	50 lb./ft.
175 N/m	12 lb./ft.
1460 N/m	100 lb./ft.
23.13 MN/m	130 kip/in.
292 kN/m	20 kip/ft.
730 kN/m	50 kip/ft.
287.28 Pa	6 psf
957.6 Pa	20 psf
366 kg/m^2	75 lb./ft.^{2}
47,880 Pa	1 Ton/ft.^{2}

UNITS USED ON DRAWINGS (Cont'd)

Stress (Pressure)	
Metric Value (MPa)	**U.S. Equivalent (psi)**
0.248	36
0.517	75
0.690	100
1.034	150
1.379	200
2.068	300
2.482	360
3.447	500
6.895	1000
8.274	1200
11.376	1650
12.411	1800
13.790	2000
20.684	3000
27.579	4000
34.474	5000
68.947	10,000
137.895	20,000
165.473	24,000
206.842	30,000
248.211	36,000
275.790	40,000
344.737	50,000
413.685	60,000
689.470	100,000
68 947	10,000,000
172 369	25,000,000
199 948	29,000,000

UNITS USED ON DRAWINGS (Cont'd)

Weight (Density)	
Metric Value (kg/m^3)	**U.S. Equivalent ($lb./ft^3$)**
480	30
801	50
961	60
1441	90
1602	100
1842	115
1922	120
2243	140
2320	145
2403	150
2482	155
2723	170
2803	175
3204	200
7208	450
7849	490

UNITS USED ON DRAWINGS (Cont'd)

Temperature	
Metric Value (°C)	**U.S. Equivalent (°F)**
-51	-60
-35	-31
-34.4	-30
-17.8	0
-17.0	1
-1.1	30
1.7	35
3.4	40
7.2	45
46.1	115
48.9	120
148.9	300

UNITS USED ON DRAWINGS (Cont'd)

Miscellaneous	
Metric Value	**U.S. Equivalent**
96.5 km/h	60 mph
160.9 km/h	100 mph
9.81 m/s^2	32.2 ft./s^2
232.77 mm^2/m	0.11 in^2/ft.
264 mm^2/m	⅛ in^2/ft.
529 mm^2/m	0.25 in^2/ft.
0.052 m/m	⅝ in/ft.
0.035 m/1000 kg	1¼ in/Ton
M13.5	H 15
M18	H 20
MS	HS
MS13.5	HS 15
MS18	HS 20
Metric Tons	Tons

UNITS USED ON DRAWINGS (Cont'd)

The following chart gives the new kPa loads that shall be used to replace the psf loads.

Metric Value (kPa)	English Equivalent (psf)	Percent Metric is Stronger
2.5	50	4.4
4	80	1.8
4.5	85	10.6
5	100	4.4
6	120	4.4
7.5	150	4.4
10	200	4.4
12	250	0.2
15	300	4.4
17	350	1.4
20	400	4.4
22	450	2.1
24	500	0.2
32	640	4.1

UNITS FOR STRUCTURAL STEEL DESIGN

Although there are seven metric base units in the SI system, only four are currently used by AISC in structural steel design. These base units are listed in the following table.

Quantity	Unit	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
temperature	celsius	°C

Similarly, of the numerous decimal prefixes included in the SI system, only three are used in steel design.

Prefix	Symbol	Order of Magnitude	Expression
mega	M	10^6	1 000 000 (one million)
kilo	k	10^3	1000 (one thousand)
milli	m	10^{-3}	0.001 (one thousandth)

In addition, three derived units are applicable to the present conversion.

Quantity	Name	Symbol	Expression
force	newton	N	$N = kg \cdot m/s^2$
stress	pascal	Pa	$Pa = N/m^2$
energy	joule	J	$J = N \cdot m$

Although specified in SI, the pascal is not universally accepted as the unit of stress. Because section properties are expressed in millimeters, it is more convenient to express stress in newtons per square millimeter ($1\ N/mm^2 = 1\ MPa$). It should be noted that the joule, as the unit of energy, is used to express energy absorption requirements for impact tests. Moments are expressed in terms of $N \cdot m$.

The following conversion factors relate traditional U.S. units of measurement to the corresponding SI units:

Multiply	by:	to obtain:
inch (in.)	25.4	millimeters (mm)
foot (ft.)	304.8	millimeters (mm)
pound-mass (lb)	0.454	kilogram (kg)
pound-force (lbf)	4.448	newton (N)
ksi	6.895	N/mm^2
ft-lbf	1.356	joule (J)

UNITS FOR STRUCTURAL STEEL DESIGN (Cont'd)

Note that fractions resulting from metric conversion should be rounded to whole millimeters. Following are common fractions of inches and their metric equivalent.

Fraction (in.)	Exact Conversion (mm)	Rounded to: (mm)
1/16	1.5875	2
⅛	3.175	3
3/16	4.7625	5
¼	6.35	6
5/16	7.9375	8
⅜	9.525	10
7/16	11.1125	11
½	12.7	13
⅝	15.875	16
¾	19.05	19
⅞	22.225	22
1	25.4	25

Bolt diameters are taken directly from the ASTM Specification A325 and A490. The metric bolt designations are as follows:

Designation	Diameter (mm)	Diameter (in.)
M16	16	0.63
M20	20	0.79
M22	22	0.87
M24	24	0.94
M27	27	1.06
M30	30	1.18
M36	36	1.42

UNITS FOR STRUCTURAL STEEL DESIGN (Cont'd)

The yield strengths of structural steels covered in the metric LRFD Specification are taken from the metric ASTM Specifications. It should be noted that the yield points are slightly different from the traditional values.

ASTM Designation	Yield stress (N/mm^2)	Yield stress (ksi)
A36M	250	36.26
A572M Gr. 345 A588M	345	50.04
A852M	485	70.34
A514M	690	100.07

On the basis of the above selection of units and conversion factors, the 1986 LRFD Specification has been translated into the SI system. When necessary, formulas were revised to make all coefficients non-dimensional. In most instances, this could be achieved by explicitly showing the modulus of elasticity, E, in the formulation.

The converted LRFD Specification is offered to the federal agencies and consultants as an interim document to facilitate design of metric demonstration projects. It will also serve as an introduction of the SI units of measurement to the general design profession and fabricating industry. More complete information is available in the Metric Guide for Federal Construction, First Edition, prepared by the Construction Subcommittee of the Metrication Operating Committee. The guide is available from the National Institute of Building Sciences in Washington D.C. (Call 202-289-7800 for ordering information).

AASHTO EXPRESSIONS

For convenience and completeness, a copy of the AASHTO expressions is reproduced within this manual.

U.S. Customary	Metric
Article 2.7.4.3	
$\frac{1,600}{\sqrt{F_y}}$	$\frac{133}{\sqrt{F_y}}$
$\frac{6,000}{\sqrt{F_y}}$	$\frac{499}{\sqrt{F_y}}$
$\frac{13,300}{\sqrt{F_y}}$	$\frac{1,106}{\sqrt{F_y}}$
$\frac{13,300\left[1 - 1.43\left(\frac{f_a}{F_a}\right)\right]}{\sqrt{F_y}}$	$\frac{1,106\left[1 - 1.43\left(\frac{f_a}{F_a}\right)\right]}{\sqrt{F_y}}$
$\frac{7,000}{\sqrt{F_y}}$	$\frac{581}{\sqrt{F_y}}$
$\frac{2,400b}{\sqrt{F_y}}$	$\frac{199.2b}{\sqrt{F_y}}$
$\frac{20,000,000\ A_f}{dF_y}$	$\frac{137,640\ A_f}{dF_y}$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Figure 2.7.4B	
$1 + \frac{h - 33}{18}$	$1 + \frac{h}{0.457} - \frac{33}{18}$
Article 3.8.2	
$\frac{50}{L + 125}$	$\frac{15.24}{L + 38}$
Article 3.10	
$\frac{6.68S^2}{R}$	$\frac{0.79\ S^2}{R}$
Article 3.14.1	
$\left(30 + \frac{3{,}000}{L}\right)\left(\frac{55 - W}{50}\right)$	$\left(1{,}435 + \frac{43{,}800}{L}\right)\left(\frac{16.7 - W}{15.2}\right)$
Article 3.21.1.3	
$0.32\sqrt{\frac{W}{P}}$	$\sqrt{\frac{W}{P}}$
Article 3.24.3	
$\left(\frac{S + 2}{32}\right)P_{20}$	$\left(\frac{S + .61}{9.74}\right)P_{18}$
$\left(\frac{S + 2}{32}\right)P_{15}$	$\left(\frac{S + .61}{9.74}\right)P_{13.5}$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 3.24.5.1	
$0.8X + 3.75$	$0.8X + 1.143$
$0.35X + 3.2$	$0.35X + .98$
Article 3.24.10.2	
$\frac{100}{\sqrt{S}}$	$\frac{55}{\sqrt{S}}$
$\frac{220}{\sqrt{S}}$	$\frac{121}{\sqrt{S}}$
Article 3.25.1	
$P[.51 \log_{10} s - K]$	$P[.51 \log_{10}(39.36s) - k]$
$\frac{1{,}000}{\sigma_{PL}} \times \left[\frac{\overline{R}_Y}{R_D} + \frac{\overline{M}_Y}{M_D}\right]$	$\frac{6{,}895}{\sigma_{PL}} \times \left[\frac{\overline{R}_Y}{R_D} + \frac{\overline{M}_Y}{M_D}\right]$
$\left(\frac{P}{2s}\right)(s - 20)$	$\left(\frac{P}{2s}\right)(s - 0.50)$
$\left(\frac{Ps}{1{,}600}\right)(s - 10)$	$\left(\frac{Ps}{40}\right)(s - 0.25)$
$\left[\frac{Ps}{20}\right]\left[\frac{(s - 30)}{(s - 10)}\right]$	$\left[\frac{Ps}{20}\right]\left[\frac{(s - .75)}{(s - .25)}\right]$
Article 4.4.12.2	
$5\sqrt{f'_c}$	$.415\sqrt{f'_c}$
Article 8.5.3	
0.000006 per deg F	0.0000108 per deg C
Article 8.7.1	
$w^{1.5}\sqrt{f'_c}$	$w^{1.5}(0.0428)\sqrt{f'_c}$
$57{,}000\sqrt{f'_c}$	$4{,}729.77\sqrt{f'_c}$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 8.15.2.1.1	
$7.5\sqrt{f'_c}$	$.623\sqrt{f'_c}$
$6.3\sqrt{f'_c}$	$.523\sqrt{f'_c}$
$5.5\sqrt{f'_c}$	$.456\sqrt{f'_c}$
Article 8.15.5.2.1	
$0.95\sqrt{f'_c}$	$.079\sqrt{f'_c}$
$0.9\sqrt{f'_c} + 1{,}100\,\rho_w\left(\frac{Vd}{M}\right) \leq 1.6\sqrt{f'_c}$	$0.75\sqrt{f'_c} + 7.58\,\rho_w\left(\frac{Vd}{M}\right) \leq 0.133\sqrt{f'_c}$
Article 8.15.5.2.2	
$0.9\left(1 + 0.0006\,\frac{N}{A_g}\right)\sqrt{f'_c}$	$10.84\left[.0068 + .0006\left(\frac{N}{A_g}\right)\right]\sqrt{f'_c}$
Article 8.15.5.2.3	
$0.9\left(1 + 0.0004\,\frac{N}{A_g}\right)\sqrt{f'_c}$	$10.84\left[.0068 + .004\left(\frac{N}{A_g}\right)\right]\sqrt{f'_c}$
Article 8.15.5.3.4	
$1.5\sqrt{f'_c}$	$.125\sqrt{f'_c}$
Article 8.15.5.3.8	
$2\sqrt{f'_c}$	$.166\sqrt{f'_c}$
Article 8.15.5.3.9	
$4\sqrt{f'_c}$	$.332\sqrt{f'_c}$
Article 8.15.5.6.3	
$\left(0.8 + \frac{2}{\beta_c}\right)\sqrt{f'_c} \leq 1.8\sqrt{f'_c}$	$\left(.066 + \frac{.166}{\beta_c}\right)\sqrt{f'_c} \leq .149\sqrt{f'_c}$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 8.15.5.6.4	
$0.9\sqrt{f'_c}$	$.075\sqrt{f'_c}$
$3\sqrt{f'_c}$	$.249\sqrt{f'_c}$
Article 8.15.5.7	
$\sqrt{f'_c} + 2{,}200\,\rho\frac{Vd}{M}$	$.083\sqrt{f'_c} + 15.168\,\rho\frac{Vd}{M}$
$1.8\sqrt{f'_c}$	$.149\sqrt{f'_c}$
$1.4\sqrt{f'_c}$	$.116\sqrt{f'_c}$
$1.2\sqrt{f'_c}$	$.100\sqrt{f'_c}$
Article 8.16.3.2.2	
$\frac{0.85\,\beta_1 f'_c}{f_y}\left(\frac{87{,}000}{87{,}000 + f_y}\right)$	$\frac{0.85\,\beta_1 f'_c}{f_y}\left(\frac{599.843}{599.843 + f_y}\right)$
Article 8.16.3.3.3	
$\left(\frac{b_w}{b}\right)\left[\left(\frac{0.85\,\beta_1 f'_c}{f_y}\right)\left(\frac{87{,}000}{87{,}000 + f_y}\right) + \rho_f\right]$	$\left(\frac{b_w}{b}\right)\left[\left(0.85\,\beta_1\left(\frac{f'_c}{f_y}\right)\right)\left(\frac{599.843}{599.843 + f_y}\right) + \rho_f\right]$
Article 8.16.3.4.1	
$0.85\,\beta_1\left(\frac{f'_c d'}{f_y d}\right)\left(\frac{87{,}000}{87{,}000 - f_y}\right)$	$0.85\,\beta_1\left(\frac{f'_c d'}{f_y d}\right)\left(\frac{599.843}{599.843 + f_y}\right)$
Article 8.16.3.4.3	
$\left[\frac{0.85\,\beta_1 f'_c}{f_y}\left(\frac{87{,}000}{87{,}000 + f_y}\right)\right] + \rho'\left(\frac{f_s'}{f_y}\right)$	$\left[0.85\,\beta_1\left(\frac{f'_c}{f_y}\right)\left(\frac{599.843}{599.843 + f_y}\right)\right] + \rho\left(\frac{f_s'}{f_y}\right)$
$87{,}000\left[1 - \left(\frac{d'}{d}\right)\left(\frac{87{,}000 + f_y}{87{,}000}\right)\right]$	$599.843\left[1 - \left(\frac{d'}{d}\right)\left(\frac{599.843 + f_y}{599.843}\right)\right]$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 8.16.6.2.1	
$1.9\sqrt{f'_c} + 2{,}500\,\rho_w\left(\frac{V_u d}{M_u}\right)$	$1.58\sqrt{f'_c} + 17.2\,\rho_w\left(\frac{V_u d}{M_u}\right)$
$2\sqrt{f'_c}$	$.166\sqrt{f'_c}$
$3.5\sqrt{f'_c}$	$.291\sqrt{f'_c}$
Article 8.16.6.2.2	
$2\left(1 + \frac{N_u}{2{,}000\,A_g}\right)\sqrt{f'_c}$	$24.1\left(.0068 + \frac{N_u}{2{,}000\,A_g}\right)\sqrt{f'_c}$
$2\sqrt{f'_c}$	$.166\sqrt{f'_c}$
Article 8.16.6.2.3	
$2\left(1 + \frac{N_u}{500\,A_g}\right)\sqrt{f'_c}$	$24.1\left(.0068 + \frac{N_u}{500\,A_g}\right)\sqrt{f'_c}$
Article 8.16.6.3.4	
$3\sqrt{f'_c}$	$.249\sqrt{f'_c}$
Article 8.16.6.3.8	
$4\sqrt{f'_c}$	$.332\sqrt{f'_c}$
Article 8.16.6.3.9	
$8\sqrt{f'_c}$	$.664\sqrt{f'_c}$
Article 8.16.6.6.2	
$\left(2 + \frac{4}{\beta_c}\right)\sqrt{f'_c} \leq 4\sqrt{f'_c}$	$.083\left(2 + \frac{4}{\beta_c}\right)\sqrt{f'_c} \leq .332\sqrt{f'_c}$
Article 8.16.6.6.3	
$6\sqrt{f'_c}$	$.498\sqrt{f'_c}$
$2\sqrt{f'_c}$	$.166\sqrt{f'_c}$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 8.16.6.7.1	
$2.14\sqrt{f'_c} + 4{,}600\,\rho\,\frac{V_u d}{M_u}$	$.178\sqrt{f'_c} + 31.716\,\rho\,\frac{V_u d}{M_u}$
$4\sqrt{f'_c}$	$.332\sqrt{f'_c}$
$3\sqrt{f'_c}$	$.249\sqrt{f'_c}$
$2.5\sqrt{f'_c}$	$.208\sqrt{f'_c}$
Article 8.16.8.3	
$21 - 0.33\,f_{min} + 8\,(r/h)$	$144.790 - 0.33\,f_{min} + 55.12\,(r/h)$
Article 8.19.1.2	
$\frac{50\,b_w s}{f_y}$	$\frac{.344750\,b_w s}{f_y}$
Article 8.25.1	
$\frac{0.04\,A_b f_y}{\sqrt{f'_c}}$	$\frac{18.97\,A_b f_y}{\sqrt{f'_c}}$
$0.0004\,d_b f_y$	$5.8 \times 10^{-2}\,d_b f_y$
$\frac{0.085\,f_y}{\sqrt{f'_c}}$	$\frac{0.026\,f_y}{\sqrt{f'_c}}$
$\frac{0.11\,f_y}{\sqrt{f'_c}}$	$\frac{0.034\,f_y}{\sqrt{f'_c}}$
$\frac{0.03\,d_b f_y}{\sqrt{f'_c}}$	$\frac{0.361\,d_b f_y}{\sqrt{f'_c}}$
Article 8.25.2	
$\frac{6.7\sqrt{f'_c}}{f_{ct}}$	$\frac{.556\sqrt{f'_c}}{f_{ct}}$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 8.26.1	
$\frac{0.02\, d_b f_y}{\sqrt{f'_c}}$	$\frac{0.240\, d_b f_y}{\sqrt{f'_c}}$
$0.0003\, d_b f_y$	$.043\, d_b f_y$
Article 8.30.1.2	
$\frac{0.03\, d_b(f_y - 20{,}000)}{\sqrt{f'_c}}$	$\frac{0.36\, d_b(f_y - 137.895)}{\sqrt{f'_c}}$
$0.20\ \frac{A_w}{S_w} \cdot \frac{f_y}{\sqrt{f'_c}}$	$2.4\ \frac{A_w}{S_w} \cdot \frac{f_y}{\sqrt{f'_c}}$
Article 8.30.2.1	
$0.27\ \frac{A_w}{S_w} \cdot \frac{f_y}{\sqrt{f'_c}}$	$3.24\ \frac{A_w}{S_w} \cdot \frac{f_y}{\sqrt{f'_c}}$
Article 9.15.2.1	
$3\sqrt{f'_{ci}}$	$.249\sqrt{f'_{ci}}$
$7.5\sqrt{f'_{ci}}$	$.623\sqrt{f'_{ci}}$
Article 9.15.2.2	
$6\sqrt{f'_c}$	$.498\sqrt{f'_c}$
$3\sqrt{f'_c}$	$.249\sqrt{f'_c}$
Article 9.15.2.3	
$7.5\sqrt{f'_c}$	$.623\sqrt{f'_c}$
$6.3\sqrt{f'_c}$	$.523\sqrt{f'_c}$
$5.5\sqrt{f'_c}$	$.457\sqrt{f'_c}$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 9.16.2.1.1	
$17{,}000 - 150\,RH$	$117.21 - 1.034\,RH$
$0.80\,(17{,}000 - 150\,RH)$	$0.80\,(117.21 - 1.034\,RH)$
Article 9.16.2.1.2	
$33w^{3/2}\sqrt{f'_{ci}}$	$0.428w^{3/2}\sqrt{f'_{ci}}$
Article 9.16.2.1.4	
$20{,}000 - 0.4ES - 0.2\,(SH + CR_c)$	$137.9 - 0.4ES - 0.2\,(SH + CR_c)$
$20{,}000 - 0.3FR - 0.4ES - 0.2\,(SH + CR_c)$	$137.9 - 0.3FR - 0.4ES - 0.2\,(SH + CR_c)$
$18{,}000 - 0.3FR - 0.4ES - 0.2\,(SH + CR_c)$	$124.10 - 0.3FR - 0.4ES - 0.2\,(SH + CR_c)$
Article 9.17.4.1	
$f_{sc} + 15{,}000$	$f_{sc} + 103.421$
Article 9.17.4.2	
$\frac{\ell x}{D} + \frac{2}{3} f_{sc}$	$6.895\frac{\ell x}{d} + \frac{2}{3} f_{sc}$
Article 9.20.2.2	
$0.6\sqrt{f'_c}\,b'd + V_d + \frac{V_i M_{cr}}{M_{max}}$	$4.98 \times 10^4\sqrt{f'_c}\,b'd + V_d + \frac{V_i M_{cr}}{M_{max}}$
$1.7\sqrt{f'_c}\,b'd$	$218.76\sqrt{f'_c}\,b'd$
$\frac{1}{Y_t}\,(6\sqrt{f'_c} + f_{pc} - f_d)$	$\frac{1}{Y_t}\,(0.498\sqrt{f'_c} + f_{pc} - f_d)$
Article 9.20.2.3	
$(3.5\sqrt{f'_c} + 0.3\,f_{pc})\,b'd + V_p$	$10 \times 10^5\,[(.29\sqrt{f'_c} + 0.3\,f_{pc})\,b'd] + V_p$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 9.20.3.1	
$8\sqrt{f'_c}\,b'd$	$.664\sqrt{f'_c}\,b'd$
Article 9.20.3.2	
$4\sqrt{f'_c}\,b'd$	$.332\sqrt{f'_c}\,b'd$
Article 9.20.3.3	
$\frac{50\,b's}{f_{sy}}$	$\frac{.345\,b's}{f_{sy}}$
Article 9.27.1	
$\left(f^*_{su} - \frac{2}{3}f_{sc}\right)D$	$\frac{1}{6.895}\left(f^*_{su} - \frac{2}{3}f_{sc}\right)D$
Article 10.2.2	
0.0000065 per deg F	11×10^{-6} per deg C
Article 10.15.2.1	
$\frac{14bD}{\sqrt{F_y \psi} t_w}$	$\frac{0.03675}{\sqrt{F_y \psi} t_w}$
$\frac{7500b}{F_y \psi}$	$\frac{51.69b}{F_y \psi}$
Article 10.15.3	
$\Delta_R = \frac{0.02\,L^2 Fy}{EY_n}\left(\frac{1000-R}{850}\right)$	
Article 10.16.11	
$\frac{11{,}000}{\sqrt{F_y}}$	$\frac{913}{\sqrt{F_y}}$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 10.20.2.1	
$(0.2272L - 11)\,S_d^{-2/3}$	$(0.339L - 4.98)\,S_d^{-2/3}$
$(0.059L - 0.64)\,S_d^{-1/2}$	$(0.1068L - 0.353)\,S_d^{-1/2}$
$\dfrac{72M_{cb}}{t_f b_f^2}$	$\dfrac{6M_{cb}}{t_f b_f^2}$
$M_{cb} = 0.8WS_d^2\,(\text{ft} - \text{lb})$	
Article 10.20.2.2	
$F_D = 1.14WS_d$	
Article 10.25.3	
$\left[3/4 + \dfrac{(\text{yield point of steel})}{400{,}000}\right]$	$\left[3/4 + \dfrac{(\text{yield point of steel})}{2{,}758}\right]$
Table 10.32.1A	
$F_b = \dfrac{50 \times 10^6}{S_{xc}} C_b \left(\dfrac{I_{yc}}{\ell}\right) \sqrt{\dfrac{0.772J}{I_{yc}} + 9.87\left(\dfrac{d^2}{\ell}\right)}$	
$16{,}980 - 0.53\,(KL/r)^2$	—
$23{,}580 - 1.03\,(KL/r)^2$	—
$33{,}020 - 2.02\,(KL/r)^2$	—
$47{,}170 - 4.12\,(KL/r)^2$	—
$42{,}450 - 3.33\,(KL/r)^2$	—
$\dfrac{135{,}000{,}740}{(KL/r)^2}$	—
$42{,}450 - 3.33\left(\dfrac{KL}{r}\right)^2$	$292.682 - .023\left(\dfrac{KL}{r}\right)^2$
Article 10.32.3.3.3	
$F_y\,(1 - 1.59 \times 10^{-5} f_c)$	$F_y\left(1 - \dfrac{1.59 \times 10^{-5} f_c}{.00689}\right)$
$F_y\,(1 - 1.27 \times 10^{-5} f_c)$	$F_y\left(1 - \dfrac{1.27 \times 10^{-5} f_c}{.00689}\right)$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 10.32.4.2	
$\frac{F_y - 13{,}000}{20{,}000} \times 600\,d$	$\frac{F_y - 89.50}{137.90} \times 4.137\,d$
$\frac{F_y - 13{,}000}{20{,}000} \times 3{,}000\sqrt{d}$	$\frac{F_y - 89.50}{137.90} \times 3.32\sqrt{d}$
Article 10.34.2.1.3	
$\frac{3{,}250}{\sqrt{f_b}}$	$\frac{270}{\sqrt{f_b}}$
Article 10.34.2.1.5	
$\frac{3{,}860}{\sqrt{f_{da}}}$	$\frac{320.38}{\sqrt{f_{da}}}$
Article 10.34.2.2.2	
$\frac{1{,}625}{\sqrt{f_b}}$	$\frac{134.875}{\sqrt{f_b}}$
Article 10.34.2.2.4	
$\frac{1{,}930}{\sqrt{f_{da}}}$	$\frac{160.39}{\sqrt{f_{da}}}$
Article 10.34.3.1.1	
$\frac{D\sqrt{f_b}}{23{,}000}$	$\frac{D\sqrt{f_b}}{1{,}909}$
Article 10.34.3.2.1	
$\frac{D\sqrt{f_b}}{46{,}000}$	$\frac{D\sqrt{f_b}}{3{,}818}$
Article 10.34.4.1	
$\frac{7.33 \times 10^7}{(D/t_w)^2}$	—

U.S. Customary	Metric
Article 10.34.4.2	
$\frac{6000\sqrt{K}}{\sqrt{F_y}}$	$\frac{1.52 \times 10^6 [1 + (D/d_0)^2]}{F_y (D/t_w)^2}$
$\frac{7500\sqrt{K}}{\sqrt{F_y}}$	—
$\frac{4.5 \times 10^7 K}{(D/tw)^2 Fy}$	—
Article 10.34.4.4	
$\left(0.754 - 0.34 \frac{f_v}{F_y}\right) F_y$	—
Article 10.34.5.2	
$\frac{b'\sqrt{f_b}}{2{,}250}$	$\frac{b'\sqrt{f_b}}{186.75}$
Article 10.34.6.1 and 10.34.6.2	
$\frac{b'}{12}\sqrt{\frac{F_y}{33{,}000}}$	$\frac{b'}{12}\sqrt{\frac{F_y}{227.54}}$
Article 10.35.1	
$\frac{P}{100}\left[\frac{100}{\left(\frac{\ell}{r}\right) + 10} + \frac{\left(\frac{\ell}{r}\right) F_y}{3{,}300{,}000}\right]$	$\frac{P}{100}\left[\frac{100}{\left(\frac{\ell}{r}\right) + 10} + \frac{\left(\frac{\ell}{r}\right) F_y}{22{,}754}\right]$
Article 10.35.2.3	
$\frac{1{,}625}{\sqrt{f_a}}$	$\frac{134{,}875}{\sqrt{f_a}}$
Article 10.35.2.5	
$\frac{4{,}000}{\sqrt{f_a}}$	$\frac{332}{\sqrt{f_a}}$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 10.35.2.7	
$\frac{5{,}000}{\sqrt{f_a}}$	$\frac{415}{\sqrt{f_a}}$
Article 10.35.2.9	
$\frac{6{,}000}{\sqrt{f_a}}$	$\frac{498}{\sqrt{f_a}}$
Article 10.37.2.1	
$\frac{5{,}000}{\sqrt{f_a}}$	$\frac{415}{\sqrt{f_a}}$
Article 10.37.2.2	
$\frac{7{,}500}{\sqrt{f_a}}$	$\frac{622.5}{\sqrt{f_a}}$
Article 10.37.2.3	
$\frac{10{,}000}{\sqrt{f_a}}$	$\frac{830}{\sqrt{f_a}}$
Article 10.37.2.4	
$\sqrt{\frac{1{,}625}{f_a + \frac{f_b}{3}}}$	$\sqrt{\frac{134.9}{f_a + \frac{f_b}{3}}}$
Article 10.37.3.1	
$\frac{4{,}250}{\sqrt{f_a + f_b}}$	$\frac{352.75}{\sqrt{f_a + f_b}}$
Article 10.37.3.2	
$\frac{1{,}625}{\sqrt{f_a + f_b}}$	$\frac{134.9}{\sqrt{f_a + f_b}}$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 10.38.5.1.2	
$550\left(h + \frac{t}{2}\right) W \sqrt{f'_c}$	$45.7 \times 10^6 \left(h + \frac{t}{2}\right) W \sqrt{f'_c}$
$w^{3/2}\, 33 \sqrt{f'_c}$	$w^{3/2} (.0428) \sqrt{f'_c}$
Article 10.39.4.2.1	
$\frac{6,140}{\sqrt{F_y}}$	$\frac{509.62}{\sqrt{F_y}}$
Article 10.39.4.2.2	
$.55\, F_y - 0.224\, F_y \left[1 - \sin\left(\frac{\pi}{2} \times \frac{13,300 - b \frac{\sqrt{F_y}}{t}}{7,160}\right)\right]$	$.55\, F_y - 0.224\, F_y \left[1 - \sin\left(\frac{\pi}{2} \times \frac{1,104 - b \frac{\sqrt{F_y}}{t}}{594}\right)\right]$
Article 10.39.4.2.3	
$\frac{13,300}{\sqrt{F_y}}$	$\frac{1,103.9}{\sqrt{F_y}}$
$57.6\left(\frac{t}{b}\right)^2 \times 10^6$	$396,854\left(\frac{t}{b}\right)^2$
Article 10.39.4.3.2	
$\frac{3,070 \sqrt{k}}{\sqrt{F_y}}$	$\frac{254.810 \sqrt{k}}{\sqrt{F_y}}$
Articles 10.39.4.3.4 and 10.39.4.4.4	
$\frac{6,650 \sqrt{k}}{\sqrt{F_y}}$	$\frac{551.950 \sqrt{k}}{\sqrt{F_y}}$
$.55\, F_y - 0.224\, F_y \left[1 - \sin\left(\frac{\pi}{2} \times \frac{6,650 \sqrt{k} - \frac{w \sqrt{F_y}}{t}}{3,580 \sqrt{k}}\right)\right]$	$.55\, F_y - 0.224\, F_y \left[1 - \sin\left(\frac{\pi}{2} \times \frac{552 \sqrt{k} - \frac{w \sqrt{F_y}}{t}}{297 \sqrt{k}}\right)\right]$
$14.4\, k \left(\frac{t}{w}\right)^2 \times 10^6$	$9.94\, k \left(\frac{t}{w}\right)^2 \times 10^4$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 10.39.4.5.1	
$\frac{2{,}600}{\sqrt{F_y}}$	$\frac{216}{\sqrt{F_y}}$
Article 10.48.1.1	
$\frac{2{,}055}{\sqrt{F_y}}$	—
$\frac{19{,}230}{\sqrt{F_y}}$	—
Article 10.48.2.1	
$\frac{2{,}200}{\sqrt{F_y}}$	$\frac{182.6}{\sqrt{F_y}}$
$\frac{15{,}400}{\sqrt{F_y}}$	—
$\frac{20{,}000{,}000\ A_f}{F_y d}$	
$\frac{15{,}400}{\sqrt{F_y}}$	$\frac{1{,}379 \times 10^8\ A_f}{F_y d}$
$1.015 \times 10^8 \frac{t_w^3}{D}$	$6{,}998.43 \times 10^8 \frac{t_w^3}{D}$
Article 10.48.4	
$Rb = 1 - 0.002 \left(\frac{D_c t_w}{A_{fc}}\right) \left[\frac{D_c}{t_w} - \frac{\lambda}{\sqrt{Mr/Sxc}}\right] \leq 1$	—
$\lambda = 15{,}900$ $\lambda = 12{,}500$	
$Mr = 91 \times 10^6 \left(\frac{I_{yc}}{L_b}\right) \sqrt{0.772 \frac{J}{I_{yc}} + 9.87 \left(\frac{d}{L_b}\right)^2}$	—
$\frac{18{,}250}{\sqrt{F_y}}$	
$L_r = \left[\frac{572 \times 10^6\ I_{yc} d}{F_y\ S_{xc}}\right]^{1/2}$	—

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 10.48.5.1	
$\frac{36,500}{\sqrt{F_y}}$	$\frac{3,029.5}{\sqrt{F_y}}$
Article 10.48.5.3	
$\frac{2,600}{\sqrt{F_y}}$	—
Article 10.48.6.1	
$\frac{73,000}{\sqrt{F_y}}$	$\frac{6,059}{\sqrt{F_y}}$
Article 10.48.6.3	
$\frac{d_o \sqrt{F_y}}{23,000}$	$\frac{d_o \sqrt{F_y}}{1,909}$
Article 10.48.8.1	
$V_p \left[c + \frac{0.87(1-c)}{\sqrt{1+(do/D)^2}}\right]$	—
$V_p = 0.58\, F_y D_{tw}$	—
$\frac{6000\sqrt{k}}{\sqrt{F_y}}$	—
$\frac{7500\sqrt{k}}{\sqrt{F_y}}$	—
$\frac{4.5 \times 10^7}{(D/_{tw})^2} F_y$	—
Article 10.49.2	
$\frac{18,250}{\sqrt{F_y}}$	$\frac{1,514.75}{\sqrt{F_y}}$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 10.49.3.2	
$\frac{36{,}500}{\sqrt{F_y}}$	$\frac{3{,}029.5}{\sqrt{F_y}}$
Article 10.50	
$\frac{2{,}200}{\sqrt{1.3\, f_{dl}}}$	$\frac{182.6}{\sqrt{1.3\, f_{dl}}}$
Article 10.51.5.1	
$\frac{6{,}140}{\sqrt{F_y}}$	$\frac{509.62}{\sqrt{F_y}}$
Article 10.51.5.2	
$\frac{13{,}300}{\sqrt{F_y}}$	$\frac{1{,}103.9}{\sqrt{F_y}}$
$\frac{13{,}300 - \frac{b}{t}\sqrt{F_y}}{7{,}160}$	$\frac{1{,}103.9 - \frac{b}{t}\sqrt{F_y}}{594}$
Article 10.51.5.3	
$\frac{13{,}300}{\sqrt{F_y}}$	$\frac{1.103.9}{\sqrt{F_y}}$
$105\left(\frac{t}{b}\right)^2 \times 10^6$	$.724\left(\frac{t}{b}\right)^2 \times 10^6$
Article 10.51.5.4.1	
$\frac{3{,}070\sqrt{k}}{\sqrt{F_y}}$	$\frac{254.81\sqrt{k}}{\sqrt{F_y}}$
Article 10.51.5.4.2	
$\frac{6{,}650\sqrt{k}}{\sqrt{F_y}}$	$\frac{552\sqrt{k}}{\sqrt{F_y}}$
$\frac{6{,}650\sqrt{k} - \frac{w}{t}\sqrt{F_y}}{3{,}580\sqrt{k}}$	$\frac{552\sqrt{k} - \frac{w}{t}\sqrt{F_y}}{297\sqrt{k}}$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 10.51.5.4.3	
$26.2\,k\left(\frac{t}{w}\right)^2 \times 10^6$	$.181\,k\left(\frac{t}{w}\right)^2 \times 10^6$
$\frac{6{,}650\sqrt{k}}{\sqrt{F_y}}$	$\frac{552\sqrt{k}}{\sqrt{F_y}}$
Article 10.51.5.5	
$\frac{2{,}600}{\sqrt{F_y}}$	$\frac{215.8}{\sqrt{F_y}}$
Article 10.55.2	
$\frac{6{,}750}{\sqrt{f_a}}$	$\frac{560}{\sqrt{f_a}}$
$\frac{10{,}150}{\sqrt{f_a}}$	$\frac{8{,}425}{\sqrt{f_a}}$
$\frac{13{,}500}{\sqrt{f_a}}$	$\frac{1{,}121}{\sqrt{f_a}}$
$\sqrt{\frac{2{,}200}{f_a + \frac{f_b}{3}}}$	—
Article 10.55.3	
$\frac{5{,}700}{\sqrt{f_a + f_b}}$	$\frac{473}{\sqrt{f_a + f_b}}$
$\frac{2{,}200}{\sqrt{f_a + f_b}}$	$\frac{182.6}{\sqrt{f_a + f_b}}$
Article 13.3.3.2	
$\frac{L + \frac{3}{8}}{L}$	$\frac{L + 0.010}{L}$
Article 13.3.7.1	
$(12/d)^{1/9}$	$(.3/d)^{1/9}$

AASHTO EXPRESSIONS (Cont'd)

U.S. Customary	Metric
Article 16.3.4	
$f_u - \left[\frac{f_u^2}{48E} \times \left(\frac{kD}{r}\right)^2\right]$	$f_u - \left[\frac{f_u^2}{48E} \times \left(\frac{kD}{3.28\,r}\right)^2\right]$
Article 17.7.4.7	
$\frac{98}{\sqrt[3]{d_c A}}$	$\frac{17.2}{\sqrt[3]{d_c A}}$

CHAPTER FIVE

Materials

The following standards are given as recommendations to the conversion of Materials activities to the metric system.

- The Materials Manual must be converted to metric units for use on pilot projects for 1994 and general use in 1995.
- All equipment must be calibrated using metric units.
- All existing and new software programs must be able to accommodate metrication.
- Programs written specifically for materials testing must be modified to accommodate metrication with the assistance of Information Systems personnel.

UNITS

Quantity	Unit	Symbol
length	millimeter meter kilometer	mm m km
area	square millimeter square meter	mm^2 m^2
volume	liter cubic meter	L m^3
mass	gram kilogram metric ton	g kg Metric Ton
temperature	degree Celsius	°C

STRUCTURAL STEEL

The American Institute of Steel Construction has available their publication "Metric Properties of Structural Shapes with Dimensions According to ASTM A6M," the metric version of Part 1 of the Manual of Steel Construction. This publication basically provides a soft conversion for all conventional U.S. measurements for structural steel shapes to metric units.

There are three dominant world steel shape standards:

1. ASTM A6/A6M, American
2. JIS, Japanese Industrial Standard
3. DIN, Deutsches Instituet fuer Normung, (German)

A fourth is the BI, or British Imperial. None is dominant worldwide, but each is used extensively. There is no international standard issued by ISO (International Standards Organization), the official international group that develops worldwide standards.

The ISO standard is currently undergoing development, and will probably involve selection of shapes from the three primary world standards, coupled with elimination of redundant shapes.

Since no international trend exists on standardization of steel shapes, AISC recommends that metric projects use the same steel shapes currently used, only use the metric dimensions listed in ASTM A6/A6M. A6/A6M lists both inch and mm dimensions of the shapes. All LRFD property, shape, and specification design data is available in metric from AISC for A6/A6M steel shapes (Phone orders: AISC, Chicago, IL, 312-670-5414). Structural calculations should be done in metric.

Fasteners

- Large projects must use ASTM A325, A490, and A615 metric bolts. The primary benefit of using these new sizes is that there is a reduction in the number of bolts, from nine to seven.

Metric Bolt Designation	Diameter mm (in.)	English Substitution
M16	16 (0.63)	⅝
M20	20 (0.79)	-
M22	22 (0.87)	⅞
M24	24 (0.94)	-
M27	27 (1.06)	1⅛
M30	30 (1.18)	1¼
M36	36 (1.42)	-

STRUCTURAL STEEL (Cont'd)

Fasteners (Cont'd)

Many firms can make the hard metric sizes. Minimum order quantities may apply for a period of time. Until these products become standard, verify that your project has sufficient quantity to meet minimum requirements.

Standard Hole Diameters					
Bolts mm (in.)		Holes mm (in.)		M-Bolts mm	Holes mm
12.7	½	14.3	9/16	-	-
15.9	⅝	17.5	11/16	M16	18
19.0	¾	20.6	13/16	-	-
-	-	-	-	M20	22
22.2	⅞	23.8	15/16	M22	24
-	-	-	-	M24	26
25.4	1	27.0	1-1/16	-	-
28.6	1⅛	30.2	1-3/16	M27	30
31.8	1¼	33.3	1-5/16	M30	33
34.9	1⅜	36.5	1-7/16	-	-
-	-	-	-	M36	39
38.1	1½	39.7	1-9/16	-	-

STEEL FABRICATION

Many firms have the capability of fabricating steel from metric design drawings. Some of these firms are:

Havens Steel, Kansas City, MO (Contact: 816-231-5724).
Steelco Div., Metropolitan Steel, Sinking Spring, PA (Contact: Ron Keating, 215-678-6411).

REINFORCING STEEL

Metric projects will use ASTM A615M reinforcing bars, which come in Grades 300 and 400 (indicating 300 and 400 MPa yield strengths), for general purpose applications. Metric rebars vary based on round values of cross-sectional area, which are specified by nominal diameter at 5 mm increments. There are 8 bar sizes, which replace the 11 bar sizes currently being used. While many firms can make metric rebar, minimum order quantities apply. It should be determined for each project if metric rebar is feasible, or if existing sizes should be used.

The following table shows the available metric rebar sizes and the current U.S. customary rebar sizes in relationship to the respective diameters and cross-sectional areas.

Metric Bar Designation	U.S. Customary Designation	Customary English System		Metric Equivalent	
		Diameter (in.)	Area (in^2)	Diameter (mm)	Area (mm^2)
	#3	0.375	0.11	9.5	71
10				11.3	100
	#4	0.500	0.20	12.7	127
	#5	0.625	0.31	15.9	198
15				16.0	200
	#6	0.750	0.44	19.1	285
20				19.5	300
	#7	0.875	0.60	22.2	388
25				25.2	500
	#8	1.000	0.79	25.4	507
	#9	1.125	1.00	28.6	641
30				29.9	700
	#10	1.270	1.27	32.3	817
35				35.7	1000
	#11	1.410	1.56	35.8	1007
	#14	1.693	2.25	43.0	1452
45				43.7	1500
55				56.4	2500
	#18	2.257	4.00	57.3	2581

STEEL PLATE

Metric Value (mm)	English Equivalent (in.)
5	0.1969
5.5	0.2165
6	0.2362
7	0.2756
8	0.3150
9	0.3543
10	0.3937
11	0.4331
12	0.4724
14	0.5512
16	0.6299
18	0.7087
20	0.7874
22	0.8661
25	0.9843
28	1.1024
30	1.1811
32	1.2598
35	1.3780
38	1.4961
40	1.5748
45	1.7717
50	1.9685
55	2.1654
60	2.3622

NOTE: Over 60 mm up to 200 mm increase in 10 mm increments, and over 200 mm in 50 mm increments (Based on ANSI Standard B323)

SHEET METAL

Most specification references use gage number followed by the decimal inch thickness.

Example: 22 gage (0.034 inch)

Metric specifications use the absolute mm thickness. It is not the intent of this guidance to change the thickness of currently used sheeting.

The following chart may be used to specify sheet metal. The thickness under "Specify" is thinner than the actual gage thickness, since specifications give minimum thickness.

Gage	Inch	Exact (mm)	Specify (mm)	Percent Thinner Than "Exact" Value
32	0.0134	0.3404	0.34	0.1
30	0.0157	0.3988	0.39	2.2
28	0.0187	0.4750	0.47	1.1
26	0.0217	0.5512	0.55	0.2
24	0.0276	0.7010	0.70	0.1
22	0.0336	0.8534	0.85	0.4
20	0.0396	1.0058	1.0	0.6
18	0.0516	1.3106	1.3	0.8
16	0.0635	1.6129	1.6	0.8
14	0.0785	1.9939	1.9	4.7
12	0.1084	2.7534	2.7	1.9
10	0.1382	3.5103	3.5	0.3
8	0.1681	4.2697	4.2	1.6

This schedule was developed since no existing material was found to clearly identify existing sheeting in metric units. Until a more efficient method is developed to address this issue, specifiers may wish to retain the gage number in specifications, and couple this with a rounded mm size in parenthesis.

STEEL WIRE STRAND

Mechanical Properties of Stainless and Heat-Resisting Steel Wire Strand					
Nominal Diameter of Strand, mm (in.)	Number of Wires in Strand	Nominal Diameter of Stainless Wires, mm (in.)	Approx. Weight of Strand per 304.8 m (1000 ft.), kg (lb)	Minimum Breaking Strength of Strand kN (lbf)	
				Medium Strength	High Strength
5.16 (13/64)	3	2.36 (0.093)	32.66 (72)	14.01 (3,150)	20.02 (4,500)
5.56 (7/32)	3	2.64 (0.104)	40.82 (90)	17.57 (3,950)	25.13 (5,650)
6.35 (¼)	3	3.05 (0.120)	54.43 (120)	23.58 (5,300)	33.58 (7,550)
7.94 (5/16)	3	3.68 (0.145)	79.38 (175)	34.25 (7,700)	48.93 (11,000)
9.52 (⅜)	3	4.19 (0.165)	102.06 (225)	44.48 (10,000)	63.61 (14,300)
5.56 (7/32)	7	1.83 (0.072)	45.36 (100)	20.02 (4,500)	28.02 (6,300)
6.35 (¼)	7	2.11 (0.083)	59.87 (132)	26.47 (5,950)	37.81 (8,500)
7.14 (9/32)	7	2.36 (0.093)	75.75 (167)	32.69 (7,350)	46.71 (10,500)
7.94 (5/16)	7	2.64 (0.104)	94.35 (208)	40.92 (9,200)	58.72 (13,200)
9.52 (⅜)	7	3.05 (0.120)	126.10 (278)	55.60 (12,500)	80.07 (18,000)
11.11 (7/16)	7	3.68 (0.145)	183.71 (405)	80.96 (18,200)	115.65 (26,000)
12.70 (½)	7	4.19 (0.165)	238.14 (525)	104.98 (23,600)	149.90 (33,700)
9.52 (⅜)	19	1.90 (0.075)	133.81 (295)	52.49 (11,800)	74.73 (16,800)
11.11 (7/16)	19	2.21 (0.087)	181.44 (400)	70.28 (15,800)	100.08 (22,500)
12.70 (½)	19	2.54 (0.100)	240.40 (530)	93.41 (21,000)	133.45 (30,000)
14.29 (9/16)	19	2.79 (0.110)	290.30 (640)	112.98 (25,400)	161.02 (36,200)
15.88 (⅝)	19	3.18 (0.125)	374.21 (825)	146.79 (33,000)	209.07 (47,000)
19.05 (¾)	19	3.81 (0.150)	539.78 (1,190)	211.29 (47,500)	300.25 (67,500)
22.22 (⅞)	19	4.44 (0.175)	734.82 (1,620)	284.69 (64,000)	406.57 (91,400)

NOTE: The diameter of the individual wires forming the strand shall not vary from the nominal wire diameters by more than ±0.025 mm (±0.001 in.).

SEVEN-WIRE, UNCOATED STRAND FOR PRESTRESSED CONCRETE STRUCTURES

The prestressing industry again uses the soft conversion for all dimensional units of prestressing wire. This soft conversion is utilized worldwide and a copy of the equivalent physical properties for Grade 270 low-relaxation strand, as provided by Florida Wire and Cable Company, is provided below.

270 GRADE LOW-RELAXATION ASTM A-416					
Nominal Strand Diameter		Minimum Strength		Area	
(mm)	(in.)	(kN)	(lb.)	(mm^2)	(in^2)
10	(3/8)	102.3	(23,000)	54.8	(0.085)
11	(7/16)	137.9	(31,000)	74.2	(0.115)
12	(15/32)	160.1	(36,000)	85.8	(0.133)
13	(½)	183.7	(41,300)	98.7	(0.153)
14	(9/16)	230.0	(51,700)	123.9	(0.192)
15	(0.600)	260.6	(58,600)	140.0	(0.217)

CONCRETE

Concrete strength is specified in megapascals (MPa). The following strengths are standard in federal metric construction. The general purpose concrete strengths are reduced from 6 strengths to 4 strengths.

Strengths above 35 MPa shall be specified in 5 MPa intervals (40, 45, 50, 55, etc.).

Metric Value (MPa)	English Value (psi)	Specify (MPa)
17.23	2500	20
20.67	3000	20 or 25*
24.12	3500	25
27.56	4000	30
31.01	4500	35
34.45	5000	35

* If code requires 3000 psi, then 25 MPa must be used, otherwise it is a professional judgement on 20 or 25.

SIEVES

Sieve Designation, (W)		Nominal Sieve Opening (in.)[C]	Permissible Variation of Average Opening from the Standard Sieve Designation (y)	Intermediate Tolerance (z)[G]	Maximum Individual Opening (x)	Nominal Wire Diameter (mm[A])
Standard[B]	Alternative					
125 mm	5 in.	5	±3.70 mm	130.0 mm	130.9 mm	8.00
106 mm	4.24 in.	4.24	±3.20 mm	110.2 mm	111.1 mm	6.40
100 mm[D]	4 in.[D]	4	±3.00 mm	104.0 mm	104.8 mm	6.30
90 mm	3½ in.	3.5	±2.70 mm	93.6 mm	94.4 mm	6.08
75 mm	3 in.	3	±2.20 mm	78.1 mm	78.7 mm	5.80
63 mm	2½ in.	2.5	±1.90 mm	65.6 mm	66.2 mm	5.50
53 mm	2.12 in.	2.12	±1.60 mm	55.2 mm	55.7 mm	5.15
50 mm[D]	2 in.[D]	2	±1.50 mm	52.1 mm	52.6 mm	5.05
45 mm	1¾ in.	1.75	±1.40 mm	46.9 mm	47.4 mm	4.85
37.5 mm	1½ in.	1.5	±1.10 mm	39.1 mm	39.5 mm	4.59
31.5 mm	1¼ in.	1.25	±1.00 mm	32.9 mm	33.2 mm	4.23
26.5 mm	1.06 in.	1.06	±0.80 mm	27.7 mm	28.0 mm	3.90
25.0 mm[D]	1 in.[D]	1	±0.80 mm	26.1 mm	26.4 mm	3.80
22.4 mm	⅞ in.	0.875	±0.70 mm	23.4 mm	23.7 mm	3.50
19.0 mm	¾ in.	0.750	±0.60 mm	19.9 mm	20.1 mm	3.30
16.0 mm	⅝ in.	0.625	±0.50 mm	16.7 mm	17.0 mm	3.00
13.2 mm	0.530 in.	0.530	±0.41 mm	13.83 mm	14.05 mm	2.75
12.5 mm[D]	½ in.[D]	0.500	±0.39 mm	13.10 mm	13.31 mm	2.67
11.2 mm	7/16 in.	0.438	±0.35 mm	11.75 mm	11.94 mm	2.45
9.50 mm	⅜ in.	0.375	±0.30 mm	9.97 mm	10.16 mm	2.27
8.00 mm	5/16 in.	0.312	±0.25 mm	8.41 mm	8.58 mm	2.07
6.70 mm	0.265 in.	0.265	±0.21 mm	7.05 mm	7.20 mm	1.87
6.30 mm[D]	¼ in.[D]	0.250	±0.20 mm	6.64 mm	6.78 mm	1.82
5.60 mm	No. 3½[E]	0.223	±0.18 mm	5.90 mm	6.04 mm	1.68
4.75 mm	No. 4	0.187	±0.15 mm	5.02 mm	5.14 mm	1.54
4.00 mm	No. 5	0.157	±0.13 mm	4.23 mm	4.35 mm	1.37
3.35 mm	No. 6	0.132	±0.11 mm	3.55 mm	3.66 mm	1.23
2.80 mm	No. 7	0.11	±0.095 mm	2.975 mm	3.070 mm	1.10

[A] The average diameter of the warp and of the shoot wires, taken separately, of the cloth of any sieve shall not deviate from the nominal values by more than the following:
Sieves coarser than 600 μm → 5% Sieves 600 to 125 μm → 7½% Sieves finer than 125 μm → 10%

[B] These standard designations correspond to the values for test sieve apertures recommended by the International Standards Organization, Geneva, Switzerland.

[C] Only approximately equivalent to the metric values in Column 1.

[D] These sieves are not in the standard series, but they have been included because they are in common usage.

[E] These numbers (3½ to 635) are the approximate number of openings per linear in., but it is preferred that the sieve be identified by the standard designation in mm or μm.

[F] 1000 μm - 1 mm.

[G] Not more than 5% of the openings may fall between the limits set by the values in Column 5 and Column 6.

SIEVES (Cont'd)

Sieve Designation, (W)		Nominal Sieve Opening (in.)[C]	Permissible Variation of Average Opening from the Standard Sieve Designation (y)	Intermediate Tolerance (z)[G]	Maximum Individual Opening (x)	Nominal Wire Diameter (mm[A])
Standard[B]	Alternative					
2.36 mm	No. 8	0.0937	±0.080 mm	2.515 mm	2.600 mm	1.00
2.00 mm	No. 10	0.0787	±0.070 mm	2.135 mm	2.215 mm	0.900
1.70 mm	No. 12	0.0661	±0.060 mm	1.820 mm	1.890 mm	0.810
1.40 mm	No. 14	0.0555	±0.050 mm	1.505 mm	1.565 mm	0.725
1.18 mm	No. 16	0.0469	±0.045 mm	1.270 mm	1.330 mm	0.650
1.00 mm	No. 18	0.0394	±0.040 mm	1.080 mm	1.135 mm	0.580
850 µm[F]	No. 20	0.0331	±35 µm	925 µm	970 µm	0.510
710 µm	No. 25	0.0278	±30 µm	775 µm	815 µm	0.450
600 µm	No. 30	0.0234	±25 µm	660 µm	695 µm	0.390
500 µm	No. 35	0.0197	±20 µm	550 µm	585 µm	0.340
425 µm	No. 40	0.0165	±19 µm	471 µm	502 µm	0.290
355 µm	No. 45	0.0139	±16 µm	396 µm	425 µm	0.247
300 µm	No. 50	0.0117	±14 µm	337 µm	363 µm	0.215
250 µm	No. 60	0.0098	±12 µm	283 µm	306 µm	0.180
212 µm	No. 70	0.0083	±10 µm	242 µm	263 µm	0.152
180 µm	No. 80	0.0070	±9 µm	207 µm	227 µm	0.131
150 µm	No. 100	0.0059	±8 µm	174 µm	192 µm	0.110
125 µm	No. 120	0.0049	±7 µm	147 µm	163 µm	0.091
106 µm	No. 140	0.0041	±6 µm	126 µm	141 µm	0.076
90 µm	No. 170	0.0035	±5 µm	108 µm	122 µm	0.064
75 µm	No. 200	0.0029	±5 µm	91 µm	103 µm	0.053
63 µm	No. 230	0.0025	±4 µm	77 µm	89 µm	0.044
53 µm	No. 270	0.0021	±4 µm	66 µm	76 µm	0.037
45 µm	No. 325	0.0017	±3 µm	57 µm	66 µm	0.030
38 µm	No. 400	0.0015	±3 µm	48 µm	57 µm	0.025
32 µm	No. 450	0.0012	±3 µm	42 µm	50 µm	0.028
25 µm[D]	No. 500	0.0010	±3 µm	34 µm	41 µm	0.025
20 µm[D]	No. 635	0.0008	±3 µm	29 µm	35 µm	0.020

[A] The average diameter of the warp and of the shoot wires, taken separately, of the cloth of any sieve shall not deviate from the nominal values by more than the following:
Sieves coarser than 600 µm → 5%   Sieves 600 to 125 µm → 7½%   Sieves finer than 125 µm → 10%

[B] These standard designations correspond to the values for test sieve apertures recommended by the International Standards Organization, Geneva, Switzerland.

[C] Only approximately equivalent to the metric values in Column 1.

[D] These sieves are not in the standard series, but they have been included because they are in common usage.

[E] These numbers (3½ to 635) are the approximate number of openings per linear in., but it is preferred that the sieve be identified by the standard designation in mm or µm.

[F] 1000 µm - 1 mm.

[G] Not more than 5% of the openings may fall between the limits set by the values in Column 5 and Column 6.

HARD CONVERSIONS FOR CONSTRUCTION MATERIALS

Structural Steel, M270			
Grade	Min. Tensile Strength (MPa)	Min. Yield Strength (MPa)	Min. Yield Strength (ksi)
36	400	250	36
50	450	345	50
50W	485	345	50
70W	620	480	70

Reinforcing Bars, M31M				
Grade		Tensile and Yield Strengths		
Metric Value	English Value	Tensile Strength (MPa)	Min. Yield Strength (MPa)	Min. Yield Strength (ksi)
300	40	500	300	40
400	60	600	400	60

Common Concrete Strengths (f'c)							
Metric (MPa)	21	24	28	35	42	48	55
English (psi)	3000	3500	4000	5000	6000	7000	8000

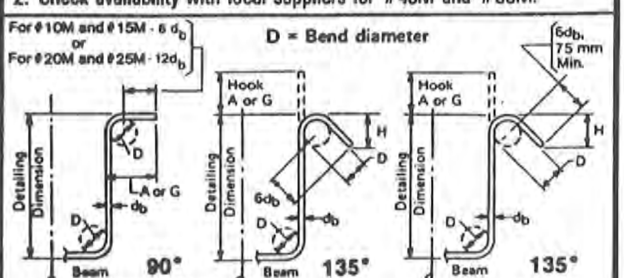
Coefficient of Thermal Expansion		
	Metric Value	English Value
Steel	0.0000117/°C	0.0000065/°F
Concrete	0.0000108/°C	0.000006/°F

Unit Weights		
	Metric Value	English Value
Steel	7848.3 kg/m^3	490 pcf
Concrete	2402.5 kg/m^3	150 pcf

ASTM STANDARD METRIC REINFORCING BARS

BAR SIZE DESIGNATION	NOMINAL DIMENSIONS MASS (kg/m)	DIAMETER (mm)	AREA (mm²)
#10M	0.785	11.3	100
#15M	1.570	16.0	200
#20M	2.355	19.5	300
#25M	3.925	25.2	500
#30M	5.495	29.9	700
#35M	7.850	35.7	1000
#45M	11.775	43.7	1500
#55M	19.625	56.4	2500

1. ASTM A615M Grade 300 is limited to size #10M through #20M.
2. Check availability with local suppliers for #45M and #55M.



STIRRUP HOOKS (Tie Bends Similar) | **SEISMIC STIRRUP/TIE**

BAR SIZE	D	90° A or G	135° A or G	H*	BAR SIZE	135° SEISMIC HOOK D	A or G	H*
#10M	50	100	100	70	#10M	50	110	70
#15M	60	140	140	90	#15M	60	140	90
#20M	120	310	200	120	#20M	120	200	120
#25M	150	400	260	150	#25M	150	260	150

*H dimension is approximate.
NOTE: All dimensions are in millimeters (mm).

CONCRETE REINFORCING STEEL INSTITUTE

CRSI

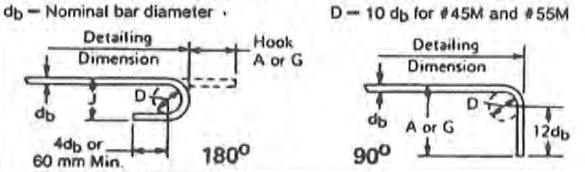
933 N. Plum Grove Road, Schaumburg, IL 60173
Phone: (708) 517-1200

STANDARD METRIC HOOK DETAILS

In accordance with ACI 318M-89

All Grades
D — Finished inside bend diameter
d_b — Nominal bar diameter

D — 6 d_b for #10M through #25M
D — 8 d_b for #30M and 35M
D — 10 d_b for #45M and #55M



RECOMMENDED END HOOKS, ALL GRADES				
BAR SIZE	D	180° HOOKS A or G	J	90° HOOKS A or G
#10M	70	140	90	180
#15M	100	180	130	260
#20M	120	220	160	320
#25M	150	280	200	400
#30M	240	400	300	500
#35M	290	460	360	600
#45M	440	660	520	780
#55M	560	860	680	1020

NOTE: All dimensions are in millimeters (mm).

STEEL TYPE	BAR SIZE RANGE	GRADE	MINIMUM YIELD, MPa	MINIMUM TENSILE, MPa
Billet A615M	#10M-#20M #10M-#55M #35M-#55M	300 400 500	300 400 500	500 600 700
Rail A616M	#10M-#35M #10M-#35M	350 400	350 400	550 600
Axle A617M	#10M-#35M #10M-#35M	300 400	300 400	500 600
Low-Alloy A706M	#10M-#55M	400	400	550

OCTOBER 1993

CHAPTER SIX

Traffic

Most of the applications of interest to the Highway Subcommittee on Traffic Engineering are conversions associated with measurements found in the *Manual on Uniform Traffic Control Devices* (MUTCD). These values include sign sizes, pavement marking widths, traffic signal lens size, etc. Please note that the following values are recommendations only.

UNITS

Quantity	Unit	Symbol
length	millimeter meter kilometer	mm m km
area	square meter	m^2
volume	liter cubic meter	L m^3
mass	metric ton	Metric Ton

SIGN CONVERSION VALUES

This list will not be exhaustive, but the principles set out should allow conversion of any value encountered.

Dimension in inches x 25 = millimeters

Typical metric sign sizes
- 300 mm
- 450 mm
- 600 mm
- 750 mm
- 900 mm
- 1050 mm
- 1200 mm
- 1350 mm
- 1500 mm

The difference between a hard conversion (1 inch = 25 mm) and a soft conversion (1 inch = 25.4 mm) is only 1.6 percent.

SIGN CONVERSION TECHNIQUES

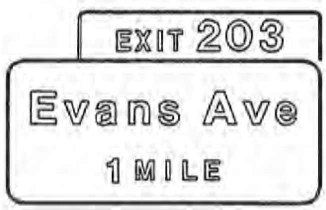
Depending on the type of sign mounting (ground mounted versus overhead mounted), the condition of the sign, the location of the sign, and the degree of legend alteration required for metric conversion, different conversion techniques are appropriate.

Signs Mounted Overhead on Bridges, Trusses, and Cantilever Supports

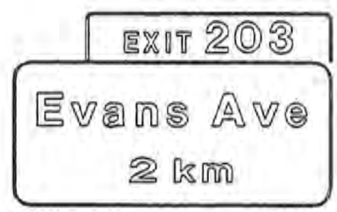
For signs mounted overhead on bridges, trusses, and cantilever supports, the following techniques are available:

- **Partial Overlay** (Using either a pop riveted aluminum panel or 3M-type sticky-back overlays) - A partial overlay is the quickest, easiest, and cheapest sign conversion technique and is appropriate if the sign panel is otherwise in good condition and only a small portion of the panel needs to be changed. A good example for the use of a partial overlay is as follows:

Convert:



To:



- **Replace Panel** - replacement will probably be required if the existing panel is in poor condition (letters peeling, defaced, bent, etc.), if the new metric legend is too large to allow simple overlaying, or if "non-preferred" sign materials are encountered (raised metallic letters, raised buttons for reflectivity, etc.). Replacing the panel is more expensive, both in materials, equipment, and labor. A crane is needed to remove the old panel and to hoist the new panel into place, which not only increases costs but also disrupts traffic flow for a longer period of time requiring more sophisticated work zone protection methods.

- **Complete Overlay** (Using an aluminum panel that is either clamped or pop riveted to the old sign panel) - This alternative to replacing the panel speeds up installation since it is not necessary to remove the old panel. It also has a lower material cost since the thickness of the aluminum sign panel that is required for overlaying is less than for sign panel replacement.

Ground Mounted Signs

For ground mounted signs, the following techniques are applicable:

- **Partial Overlay** - Partially overlaying large ground mounted signs has the same basic characteristics as partially overlaying overhead mounted signs. However, for small inexpensive ground mounted signs, such as speed limit signs and warning signs, it is often just as easy to completely replace the sign.

SIGN CONVERSION TECHNIQUES (Cont'd)

Ground Mounted Signs (Cont'd)

- **Replace Panel or Complete Overlay** - panel replacement or complete overlays are easier for ground mounted signs than for overhead signs since it is not necessary to work high above the roadway. This also reduces costs and simplifies work zone traffic controls.

- **Replace Supports** - If the sign supports are defective (slip base buried, hinges installed backwards, etc.), yet the sign panel is in good shape, the appropriate portion of the legend can be overlaid and the sign panel reinstalled on new supports. This is less expensive than installing an entirely new sign and scrapping the old one.

- **Replace Entire Sign Installation** - If both the supports and legend are in bad shape, or if the sign is in the wrong location, the sign will need to be replaced.

Depending on the situation at hand, we can expect to use most of these techniques during the metric conversion process.

BASIC SIGN TYPES

Before discussing the various design issues that are associated with metric sign conversion it is of value to identify and discuss the various types of metric distance and speed signs that are typically encountered.

Destination Signs (such as those typically encountered on freeway and arterial mainlines)

For Example:

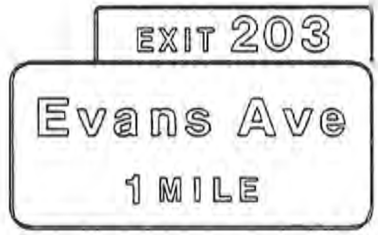
Advance Guide Signs (without exit numbering)

For Example:

BASIC SIGN TYPES (Cont'd)

Advance Guide Signs (with exit numbering)

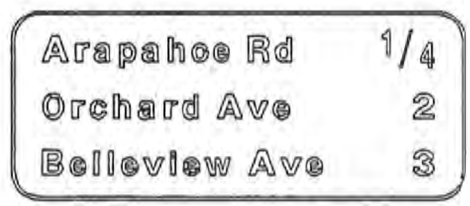
For Example:



These are typically larger freeway signs with some of them being mounted overhead, especially along urban Interstate areas. Since the bottom line of the sign is usually totally devoted to the distance, the "Exit 1 Mile" or "1 Mile" legend can be easily overlaid with an equivalent metric legend such as "Exit 2 km" or "2 km".

Interchange Sequence Signs

For Example:

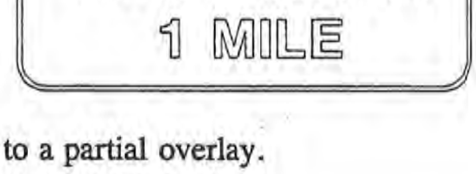


These signs are almost exclusively encountered on urban Interstate areas. They are typically situated on an overhead structure that is located within the jersey barrier that forms the median. Whether or not a partial overlay can be used depends on the relative sizes of the new metric legend and the old English legend. For example, we would like to overlay the "1/4" in the above sign with "400 m", the "2" with "3 km" and the "3" with "5 km", however, there may not be enough room to do so.

If there is insufficient room for a partial overlay, a complete overlay may be needed with abbreviations used or the "Ave", "St", "Blvd" and "Rd" words eliminated. If at all possible, we will want to avoid having to use a larger sign panel which could require expensive modification of the support structure.

Advance Rest Area/Service Center Signs (usually white on blue)

For Example:



These are freeway signs that lend themselves well to a partial overlay.

BASIC SIGN TYPES (Cont'd)

Warning Signs (black on yellow, diamond-shaped with supplemental plaque)

For Example:

Or rectangular in shape with special message.

For Example:

The smaller black on yellow diamond shape signs are typically found on arterials and, because of their small size, are good candidates for complete replacement. The larger special warning signs are typically found on freeways, with some of them being mounted overhead. These larger signs are fitting candidates for a partial overlay.

Standard Speed Limit Signs

For Example:

Given their relatively small size, complete replacement is appropriate for these signs.

BASIC SIGN TYPES (Cont'd)

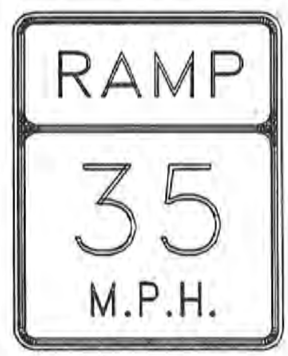
School Speed Limit Signs (Ground Mounted)

For Example:

Given their relatively small size, complete replacement is appropriate for these signs.

Ramp\Exit Speed Limit Signs

For Example:



Given their relatively small size, complete replacement is appropriate for these signs.

BASIC SIGN TYPES (Cont'd)

Advisory Speed Limit Signs (Black on Yellow - these signs are typically found in the form of supplemental plaques located blow diamond shaped warning signs)

For Example:

Given their relatively small size, complete replacement of the supplemental plaque is appropriate for those signs.

Miscellaneous Signs (Anything that does not fit into the above categories would be classified here. This includes minor directional signs which provide distance information for locations of interest such as parks, hospitals, post offices, etc.)

Conversion method will vary by type of sign, but typically will involve complete replacement.

DESIGN ISSUES

There are a number of important design issues that must be considered in converting signs to the metric system. These issues are discussed below:

Issue 1: Dualization

Dualization refers to the use of both English units and metric units to convey the same information. Dualization may involve the use of English and metric units on the same sign panel, on separate sign panels at the same location, or on separate signs in the same general area. Another form of dualization involves special "Metric equivalence" signs. These signs provide general information that allows motorists to convert from English units to metric units.

The pervasive feeling amongst those involved in sign metrication is that, in general, dualization is not a good feature. Consider the following quotes:

> "...there are strong indications that it would be desirable to avoid a transition period during which distances are shown in both English and metric units on a single sign. This could be confusing to a motorist..." (American Metric Journal, Ad Hoc Task Force Report on Metrication of U.S. Highways, May/June 1975)

Issue 1: Dualization (Cont'd)

> "Going straight to metric signing has worked well in some countries and deserves consideration. This approach will cost less and avoid confusing comparisons." (FHWA Metric Conversion Plan, June 1991)

Dualization often requires a larger sign to handle the expanded legend, which necessitates the complete replacement of the sign panel rather than the use of inexpensive overlays. The use of a larger sign panel may, in turn, require the use of larger support columns. In the case of overhead signs, the entire support structure will need to be analyzed and may need to be replaced or strengthened. The additional cost associated with dualization can be substantial.

If speeds or distances are rounded then dual legend signs can lead to confusing comparisons. For example, a distance sign that is rounded to the nearest kilometer might have the legend "Denver 1 mi 2 km", giving the indication that a mile equals 2 kilometers when a mile actually equals 1.6 kilometers.

Dualization complicates the sign legend, making it more difficult for a motorist to read and comprehend. A strong argument can also be made that dualization will allow U.S. motorists to ignore the metric portion of the legend, concentrating instead on the portion of the legend with English units. The end result will be that U.S. motorists will not "acquire a feel" for metric speeds and distances, as they would if they were forced to rely on pure metric signs.

At some point dualization will have to give way to a pure metric system. When this happens, there will be an additional cost to modify the sign legends in order to eliminate the English units.

The successful Canadian experience with "straight" metric conversion also argues against the widespread use of dualization. In addition, the FHWA is recommending that states:

> "Avoid dualization of measurements beyond FY 1993, unless it is determined that such usage will be beneficial." (FHWA Metric Conversion Plan, June 1991)

For all of those reasons we are recommending that dualization not be used in the Colorado Metric Conversion Project.

The exception would be the use of metric equivalence signs at the entrances to Colorado. In the future, when certain safety-related signs are converted to the metric system (such as load limit signs and vertical clearance signs), the use of dualization for a certain period of time might be prudent as advocated by Australia:

> "... in some instances, especially where safety is involved, both the old and new units will be given for a short period." (Manual for the Operation of Changing Signs to the Metric System, National Association of Australian State Road Authorities, 1972)

DESIGN ISSUES (Cont'd)

Issue 2: Hard Versus Soft Conversions

A "soft" conversion is a direct conversion with little or no rounding. For example, using a soft conversion approach 1 mile would become 1.6 kilometers and 55 mph would become 88 km/h. On the other hand, a "hard" conversion uses rounding to obtain values that are in even increments. Using a hard conversion approach, 1 mile would become 2 kilometers and 55 mph would become 90 km/h.

The feeling amongst those involved in sign metrication seems to be that, if possible, hard conversions should be used. This is supported by the fact that in Europe, Australia, and Canada, speed limits are given in 10 km/h increments. The FHWA also encourages the use of hard conversions, stating that the states should:

"Use hard conversions to the extent practicable." (FHWA Metric Conversion Plan June 1991)

The use of hard conversions for distance signs has two important advantages:

- Hard conversions result in shorter legends that require less sign space, which avoids a greater use of inexpensive overlays instead of expensive sign panel replacement. Soft conversions that use either fractional distances (for example: 6 1/4 km) or decimal distances (6.3 km) eat up more sign space than a hard conversion (6 km).
- Hard conversions result in sign legends that are easier to read. Also, soft conversions that use decimals can easily be misread if quickly glimpsed by a passing motorist, with 6.3 km being read as 63 km. As the sign becomes old or dirty, the chance of the decimal point becoming obscured increases.

Soft conversions have the obvious advantage of greater accuracy. But one can strongly argue that the level of accuracy needed for highway distance signing is, in reality, not very great. The following items appear to justify this assertion:

- The "Level of accuracy" of our existing English unit distance signing is most likely not too precise. In the Orlando, Florida area, a comparison was made between the distance stated on each sign and the actual distance to the location indicated on the sign. The "distance discrepancy", in both miles and percent, was noted. The distance discrepancy aggregated over all routes was about 15%, with the "average maximum" discrepancy being 57%.

DESIGN ISSUES (Cont'd)

Issue 2: Hard Versus Soft Conversions (Cont'd)

- It is often not practical, or possible, to locate signs exactly where we want them. Locational errors made during sign design or installation, the presence of physical obstructions, or the desire to reduce the number of expensive overhead structures by combining signs onto a single overhead unit, often result in distance signs being placed at other than the precise location desired. This is especially true on urban freeways where there are many exits and points of interest that need to be signed, yet only a limited number of sites for anything other than expensive overhead sign installations. In this environment, signs tend to be combined on overhead structures in a manner that clearly places practicality and cost considerations ahead of complete accuracy.

- It can be argued that the average motorist does not have an exact understanding of what certain highway distances refer to. In a recent survey, 17 motorists, of varying backgrounds, were asked to answer the following question:

  If you are driving on a freeway and see a sign that reads "Springfield *55*", does the 55 refer to:

  A) The distance from the sign to the freeway exit which leads to Springfield.

  B) The speed limit in Springfield.

  C) The distance from the sign to the City Limits of Springfield.

  D) The distance from the sign to Downtown Springfield.

  E) The population of the city of Springfield.

  As we transportation professionals know, the correct answer to the question is D. **Although all of the survey respondents had a general understanding of what the sign meant (none of them picked answers B or E), the results clearly demonstrated that most motorists do not have an exact understanding of what this common highway distance reference means** (with 10 (53%) answering C and another 3 (16%) answering A). It can be argued that, since the average motorist only has a general feel for what distance references mean, precise distance indications are not of utmost important.

The bottom line is that the accuracy provided by soft distance conversions is just not needed. The simplicity and cost savings associated with hard conversions is much more important. And, as time goes by and large distance signs deteriorate and are replaced, we can have the best of both worlds by relocating most of these signs to their exact distance locations. However, it should be noted that certain safety related signs, such as load limit and clearance signs, may require a level of accuracy that can only be obtained via soft conversions.

DESIGN ISSUES (Cont'd)

Issue 2: Hard Versus Soft Conversions (Cont'd)

The argument regarding hard and soft conversions essentially revolves around the degree of rounding that is to take place for a given sign. For this project we have developed the following policy regarding rounding on distance signs, a policy which favors simple hard conversions:

- All signs having an actual distance to the item which they refer of 800 or more meters should be rounded to the nearest even kilometer (For example: 800 m is rounded to 1 km, 1.6 km is rounded to 2 km, and 9.3 km is rounded to 9 km).
- All signs having an actual distance to the item which they refer of less than 800 meters should be rounded to the nearest 100 meters (For example: 799 m is rounded to 800 m, 656 m is rounded to 700 m, and 446 m is rounded to 400 m).

This differs from both the Australian and Canadian approach to distance rounding. The Australians use the following "softer" guidelines, which are more accurate, yet more complicated:

> "From 1 m to 999 m, 1 m increments in whole meters, followed by the symbol m; From 1 km to 4.9 km, 0.1 km increments, without the symbol km; From 5 km to 95 km, 0.5 km increments, without the symbol km; Above 10 km, 1 km increments, without the symbol km. (Manual for the Operation of Changing Signs to the Metric System, NAASRA, 1972)

For guide signs, the Canadians take a "hard" approach:

> "All distances shown on guide signs shall be in kilometers <u>rounded to the nearest whole number.</u> and shall be accompanied by the symbol "km". (Uniform Traffic Control Devices for Canada, January 1976)

However, the following statements indicate that the Canadians do not always use a hard approach for distance signing:

> "All distances displayed on warning signs and associated tab signs should be in meters, rounded to the nearest 50 m and using the symbol m." (Uniform Traffic Control Devices for Canada, January 1976)

> "Decimals, rather than fractions, should be shown in all cases." (Uniform Traffic Control Devices for Canada, January 1976)

The question of using hard or soft conversions in the cast of speed limit signs is a more difficult one giving rise to a number of engineering and legal issues. If all speed limits are converted using a hard approach which rounds to the nearest 10 km/h, then some speed limits will go up and some will go down. The biggest absolute increases in speed limits will be from 15 mph to 30 km/h (18.6 mph) - a 24% increase, from 35 mph to 60 km/h (37.3 mph) - a 6.6% increase, and from 60 mph to 100 km/h (62.2 mph) - a 3.7% increase.

Issue 2: Hard Versus Soft Conversions (Cont'd)

The use of hard conversions will undoubtedly require the modification of the legal statutes that support speed zoning. For the Interstate system, laws will need to be passed at the federal level enacting the appropriate equivalences. For other roadways, recent speed studies conducted by the Colorado Department of Transportation should be used to established the proper metric speed limit.

Since geometric design is typically based on a design speed that is 5 to 10 mph greater than the posted speed limit, a slight increase in the actual speed limit should not pose a safety risk with regard to geometrics (tapers, curves, etc.).

The signal timing issue is a bit muddier. A slight increase in a speed limit might be just enough to require an increase in traffic signal clearance intervals. However, if such an increase is needed, it could be easily made in the signal controller.

The current AASHTO Task Force on Geometric Design has recommended the adoption of design speeds in 10 km/h increments from 30 km/h thru 120 km/h, a decision that appears to support hard conversion. The use of even 10 km/h design speed increments is consistent with a hard conversion approach to posted speeds which would allow speed limits to be reasonably set at 10 km/h (6.2 mph) less than the design speed.

Michael Matthews of the University of Guelph in Guelph, Ontario completed a very interesting study on the effect on vehicle speeds when signs are switched from English units to metric units under a hard conversion process. He states that:

> "These results clearly demonstrate that the changeover to metric signing has failed to produce any significant long-term changes in travel speed parameters, even for those road sites for which metrication resulted in an increase in permitted speed". (Impacts of Highway Metrication on Traffic Accidents and Long-Term Trends in Vehicle Speeds for Roads with Resultant Increased Speed Limits, Human Factors, 1979)

Mr. Matthews also found no significant effect on accident levels and concluded that "metrication does not present the safety hazard suggested by critics of the metrication programs."

Other countries, including Canada and Australia, have "bitten the bullet" and adopted hard speed limit conversions with the exclusive use of 10 km/h speed increments. The evidence suggests that this is a safe and reasonable approach.

DESIGN ISSUES (Cont'd)

Issue 3: Partial Units

If the decision is made to use partial units (something we believe should be avoided), then decimals would be a more suitable choice over fractions. Not only do decimals take up less space on the sign, but they are more in tune with the base-10 nature of the metric system. Using decimals rather than fractions would also be more consistent with the Canadian approach.

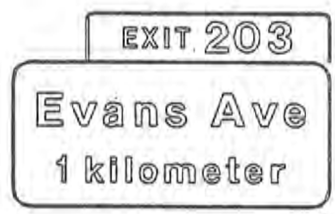
If it is decided to use decimals, we would recommend rounding to the nearest 0.5 kilometers, using decimals only for distances of less than 5 km, and using oversized decimal points to increase visibility.

Issue 4: Type of Unit Suffix

In the case of distance signs, there are 4 basic alternatives for distance suffixes:

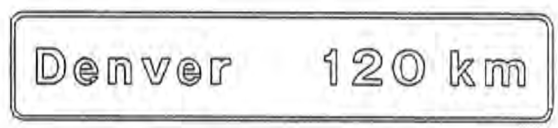
1. **Use of Complete Suffixes (kilometer and meter)**

   For Example:



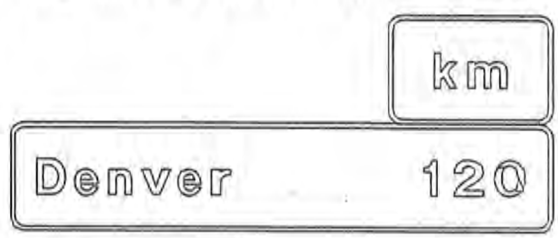
2. **Use of Abbreviated Suffixes (km and m) - Either in an adjacent arrangement for a permanent installation.**

   For Example:



Or in a supplemental plaque arrangement for temporary installation.

For Example:

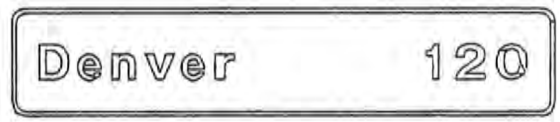


DESIGN ISSUES (Cont'd)

Issue 4: Type of Unit Suffix (Cont'd)

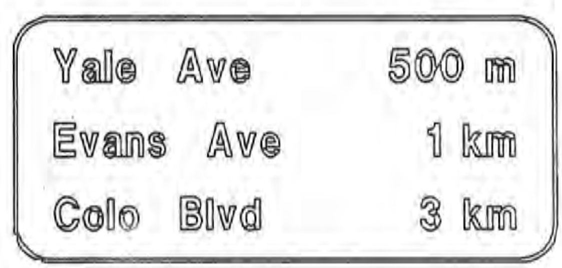
3. Use of No Suffixes

For Example:



4. Use of Mixed Abbreviated Suffixes

For Example:



Note that, in this configuration, the use of a single supplemental plaque is not possible because of the mixing of meters and kilometers.

Canada uses the abbreviated (km and m) while Australia uses the abbreviated suffix for meters (m) and no suffix for kilometers (although temporary use of the abbreviated km suffix was used in Australia during the conversion period). We have been told by a transportation engineer who previously lived in Holland that, in Europe, the abbreviated suffix is used for meters (m) while no suffix is used for kilometers unless the kilometer distance has a decimal element, in which case the abbreviated suffix (km) is used. Lower case letters are universally used for metric speed and distance units.

It is our recommendation that, consistent with the Canadian approach, exclusive use be made of the abbreviated suffixes, both in mixed and unmixed signs. This will avoid the potential confusion with miles that could result if the Australian approach is followed and the "km" is omitted. As years go by and the driving populace becomes familiar with the metric system, the "km" can be deleted; either through overlays or via sign attrition. The "m" will always be needed to differentiate distances in meters from distances in kilometers.

Unless it is absolutely necessary to save an expensive sign panel that is otherwise in good condition, we will want to avoid the use of supplementary plaques, opting for the adjacent arrangement.

Issue 5: Speed Sign Legends

All speed limit signs make use of black letters on a white background, the standard regulatory colors for speed limit signs as given in the MUTCD. However, the speed limit signs that are currently in use in Australia and Europe add a red circle around the numerals, a color that is used for regulatory purposes in the U.S. (on stop signs, yield signs, and parking signs) but not on speed limit signs. Internationally, all speed limit sign panels are rectangular in shape, with the exception of the European sign panel, which is circular. In the U.S., the circular shape is reserved for advance railroad crossing signs.

The two speed limit signs associated with Systems Technology were selected through a simulation study by Systems Technology which observed U.S. motorist reactions to metric speed signs. This study produced some interesting findings:

> "A red circle, which is consistent with international practice, gives an unambiguous cue to metric sign format. Large km/h characters also give an unambiguous cue to metric sign format." Signs with both of these features will give lower speed error rates and quicker (earlier) driver responses." (A Simulator Study of Driver Reaction to Metric Speed Signs, Systems Technology Inc, December 1979).

After considering the advantages and disadvantages of each of these speed limit signs, we chose the first of the two Systems Technology signs for use. This sign has many advantages:

- The red circle makes it highly conspicuous and clearly differentiates it from the existing U.S. speed limit sign (In fact, it is the lack of clear differentiation from the actuating U.S. speed limit sign that eliminated the Canadian speed limit sign from further consideration).

- Excluding the SPEED LIMIT legend from the sign also helps to differentiate it from the existing U.S. speed sign.

- Its rectangular shaped panel is consistent with MUTCD shape requirements for speed limit signs.

- The km/h legend makes it quite clear that it is a metric sign.

The only potential drawback to this sign is that it uses the color red in the legend. However, in our opinion this is a minor issue since other regulatory signs also use the color red and the MUTCD could be easily modified to allow this color for speed limit signs.

Since the majority of current U.S. speed signs end in 5 (about 70% of the speed signs in Colorado are either 15, 25, 35, 45, 55, or 65), rounding to the nearest 10 km/h has the added advantage of providing another source of differentiation between the English signs and the metric signs.

DESIGN ISSUES (Cont'd)

Issue 5: Speed Sign Legends

It is recommended that advisory speed limit signs be posted in increments of 10 km/h, which is consistent with both Canadian and Australian practice:

> "Advisory speeds should be posted in increments of 10 km/h." (Manual for the Operation of Changing Signs to the Metric System, NAASRA, 1972)
>
> "The speed shown [for advisory signs] should be in multiples of 10 km/h." (Uniform Traffic Control Devices for Canada, January 1976)

However, these sign panels should be square with the "km/h" legend provided below the numerals and will not have the red circle around the numerals recommended for the regular speed limit signs.

To reduce the number of signs and to show some consistency with Canada, the following directive concerning minimum speed signs should be followed:

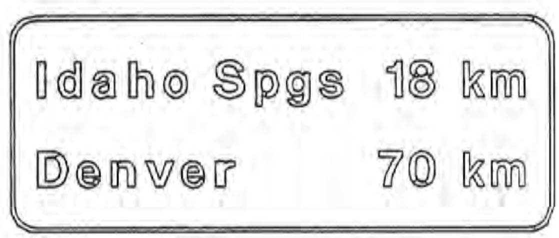
> "When both maximum and minimum Speed signs are used, the minimum speed sign shall be erected immediately below the maximum speed sign." (Uniform Traffic Control Devices for Canada, January 1976)

STANDARD CASES AND SIGN CONVERSION DETAILS

Keeping the design issues discussed in the previous section in mind, we developed a standard set of conversion cases and design details for both distance and speed signs. These items are best illustrated through examples which modify the legends presented previously for each basic sign type:

Destination Signs (without directional arrows)

Convert to:



Use complete panel replacement.

STANDARD CASES AND SIGN CONVERSION DETAILS (Cont'd)

Advance Guide Signs (without exit numbering)

Convert to:

Advance Guide Signs (with exit numbering)

Convert to:

Use partial overlay.

The Canadians adhere to the following policy in locating Advance Guide Signs:

> "The primary Advance Guide sign should be located a distance of 2 km prior to the exit gore. A preliminary Advance Guide sign at 4 km may also be employed if deemed necessary, such as at major interchanges. In cases where it is not desirable, or possible, to locate the sign at the exact 2 and 4 km points from the interchange, distances should be shown to the nearest 0.5 km." (Uniform Traffic Control Devices for Canada, January 1976)

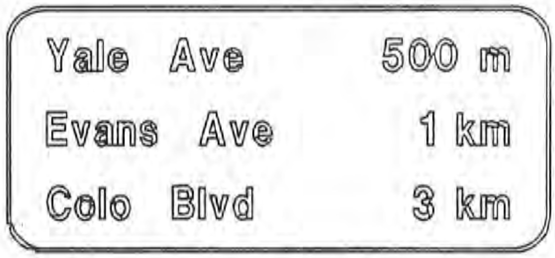
This policy seems reasonable and we would recommended following it, with the exception that all distances would be rounded to the nearest km.

Our general recommendation would be to convert all existing Advance Guide Signs with a 1 Mile legend to 2 km and all signs with a 2 Mile legend to 3 km, realizing that a distance discrepancy will occur. If at some point in the future, these signs require replacing then they would be relocated to the exact distance.

STANDARD CASES AND SIGN CONVERSION DETAILS (Cont'd)

Interchange Sequence Signs

Convert to:



If possible, use partial overlays. If this is not possible, abbreviate or eliminate "Ave", "Blvd", etc. and use complete overlay.

The Canadians adhere to the following policy concerning the use of interchange sequence signs:

> "On urban freeways having less than 2 km between interchanges, the interchange sequence signs should be used in lieu of the advance guide sign for the affected interchanges" (Uniform Traffic Control Devices for Canada, January 1976)

This policy appears reasonable and we would recommend its use. The MUTCD currently provides no quantitative guidance on this issue.

Advance Rest Area/Service Center Sign

Convert to:

Use partial overlay.

STANDARD CASES AND SIGN CONVERSION DETAILS (Cont'd)

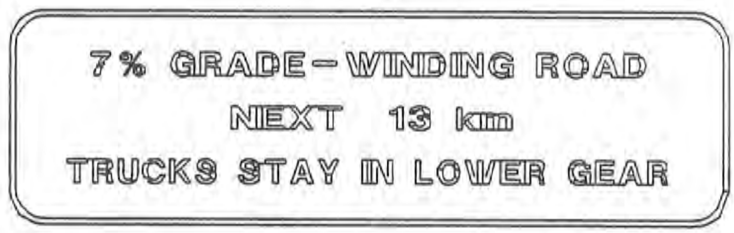
Warning Signs (Diamond-shaped with supplemental plaque)

Convert to:

Use complete panel replacement.

Or for rectangular shape sign with special message.

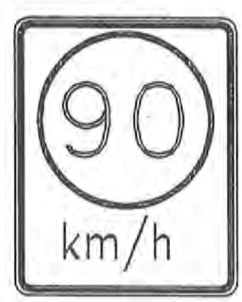
Convert to:



Use partial overlay.

Standard Speed Limit Signs

Convert to:

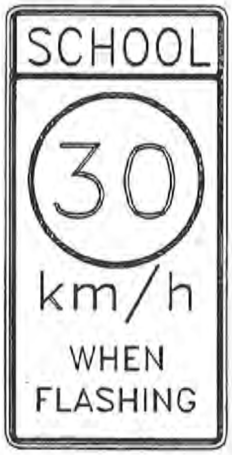


Replace entire installation.

STANDARD CASES AND SIGN CONVERSION DETAILS (Cont'd)

School Speed Limit Signs (ground mounted)

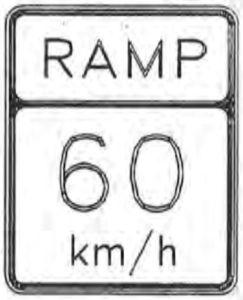
Convert to:



Use complete panel replacement.

Ramp\Exit Speed Limit Signs

Convert To:



Use complete panel replacement.

Advisory Speed Limit Signs

Convert To:

Use complete panel replacement.

WORK ZONE SIGNS

In order to provide consistency in distance and speed units on the highways covered in this project, we would recommend that all work zone signing also be converted to metric units. The Canadians have developed a series of placement standards for work zone signs. In general, advance work zone signing is placed at the 2 km, 1 km, and/or 500 m points, with supplementary distance plaques attached to the construction zone warning signs at these locations. This, of course, will require longer post lengths to meet minimum height requirements for the signs.

Since work zone signing is safety-related, the use of dualization may be appropriate for a certain time period with English unit plaques (1 mi, 1/2 mi and 1/4 mile) located directly below the metric plaques. In addition, it might be prudent to intermix English speed limits with the metric speed limits for a period of time.

Also, the "Construction, Next XX.X Miles" sign should be replaced by a metric equivalent sign rounded to the nearest kilometer.

PUBLIC AWARENESS PLAN

So that Motorists are not caught by surprise when the metric conversion takes place a public awareness campaign would be appropriate. The following campaign elements are recommended:

- Install Metric Equivalence signs on all major entrances into Colorado, adding an overlay which reads: "Signing Changes Begin in _(month/yr)_"

- Prepare radio and television spots for broadcasts 1 month prior to the beginning of sign conversion and continuing through the completion of construction.

- Install Highway Advisory Radio signs (Tune Radio to ____ AM for Metric Sign Updates") at the major entrances to Colorado and coordinate with the Colorado Tourist Development Council. These broadcasts would be used to provide greater detail on the metric conversion system.

- Consider the installation of single-post signs at the on ramps to the major grade-separated facilities. These signs would read:

  These signs would only be needed at locations where motorists are entering from a road that has not been converted to the metric system.

- Make use of permanent Variable Message Sign system to provide metric information to motorists.

- Contact the 3M Company concerning their free billboard advertising program to see if it would apply to this public project.

- Inform the American Automobile Association (AAA) and the American Trucking Association (ATA) of the changes so they can alert their members.

RECOMMENDATIONS

Based on the results of our literature search and review, and using a little common sense, the following recommendations are made:

- Avoid dualization, except for the use of metric equivalency signs at the entrances to Colorado and for safety messages.
- Use hard conversions to the maximum extent practical for distance and speed signing.
- Signs referencing distances of greater than or equal to 800 meters should be rounded to the nearest whole kilometer. Signs referencing distances of less than 800 meters should be rounded to the nearest 100 meters.
- The suffix "km" should be used for all distances expressed in kilometers and the suffix "m" should be used for all distances expressed in meters.
- Unless absolutely necessary, avoid the use of supplemental "km" tabs on separate sign panels located above the distance value. Instead, fabricate a new sign with the "km" suffix included as an integral part of the sign.
- Speed limits should be posted in even increments of 10 kilometers per hour. The federal government should be encouraged to enact appropriate enabling legislation for the interstate system. The new Metric speed limits on non-interstate facilities should be established based on recent CDOT speed studies.
- The sign legend with the large numerals inside a red circle with the "km/h" suffix below should be used for standard speed limit signing.
- Install all minimum speed signs immediately below the associated speed limit sign.
- Consider following the Canadian methodology for work zone signing with dualization used during a certain educational period.
- Implement a public awareness campaign that utilizes preconstruction "metric awareness" signing on both the mainline and on-ramps, radio and television spots, and highway advisory radio. Contact appropriate agencies (AAA, ATA, etc.) and disseminate information on the metric conversion program.

In conclusion, it should be emphasized that, in the area of sign design and construction, the "field of play" is constantly changing as existing signs are replaced or upgraded by maintenance forces. Consequently, prior to commencement of construction and during the construction process, the sign modifications reflected in our final design plans will need to be re-examined to make sure that all proposed changes are still appropriate. A significant amount of field adjustment will undoubtedly be needed.

PAVEMENT MARKINGS

Width in inches x 25 = millimeters

Typical metric widths	100 mm
	150 mm
	200 mm

Pavement marking lengths in feet x 0.30 = meters.

Typical hop-skip line of 10 feet and 30 feet = 3 m and 9 m.

The difference between a hard and soft conversion is 1.6 percent.

GENERAL PROCESS TOPICS

Contracts

- Stencils and dies will need to be stocked in both metric and English for quite a while, until all of our current signs have been replaced.

Machinery in the Sign Shop

- The machinery that is rated in ton capacity will require adjustments.
- The measuring and calibrating devices attached to existing equipment will require retro-fitted metric scales.

Field Equipment

- The Distance Measuring Instruments (DMI's) used for field inventory have a switch for conversion to kilometers.
- The vehicle odometers of course are not as easily changed and since we do a great deal of our work referencing this device, consideration should be given to ordering vehicles with meter-based odometers once our reference system is changed over.
- The radar guns will eventually require modification or replacement.

GENERAL PROCESS TOPICS (Cont'd)

Signals

- The Face Size, Mast Arm length, Cabinet Dimensions, etc. must be converted along with the entire standard when it is appropriate.

Format and Forms

- Specialized Staff Traffic forms and those with outdated units will require modification to accommodate metrication.

Manuals and References

The following manuals and references must be converted to metric units:

- Manual on Uniform Traffic Control Devices
- Supplement to the MUTCD
- Traffic Control Devices Handbook
- Highway Capacity Manual
- Traffic Engineering Handbook
- Colorado Revised Statutes
- AASHTO Guide for Selecting, Locating, and Designing Traffic Barriers
- Roadside Design Guide
- Standard Highway Signs
- Supplement to Standard Highway Signs
- School Trip Safety Program Guidelines

Standards and Specifications

- The CDOT Standard Plans/S Standards must be converted to the metric system.

Materials and Supplies

- Scales, Measuring Tapes, Measuring Wheels, Radar Guns, Drafting Templates, Sign Shop Templates and Dies must all be replaced with metric equivalents.

GENERAL PROCESS TOPICS (Cont'd)

Software and Data Files

- The Sign Layout Program will need to have the entire "letter dimensioning" file redone in metric (This will require that the FHWA or AASHTO provide us with the official spacings and other dimensions).

- All proprietary and computational software will require replacement. This includes the Highway Capacity Software, and Passer II.

Construction Unit

- Review and Revise Construction Manual (Traffic Related Items, e.g. The Inspection Signing Section (614.09) will require dimension changes along with Sections 614.10 and 630, Inspection of Traffic Signal Systems and Traffic Control Review, respectively.)

- Review and Revise Construction Specification (Traffic Related Items, i.e. A multitude of dimensioning/unit changes will be required. They are too numerous to list here. This effort will require a detailed review of each Traffic related section.)

- Review and Revise Construction Procedures (Traffic Related Items, e.g. The construction procedures and requirements are spelled out in the Specifications, Standards, and the Construction Manual and they are scheduled for modification.)

Maintenance and Materials Unit

- Review and Revise the Maintenance Manual, and the Materials Manual as well as the Roadway Design Manual (Traffic Related Items). A multitude of dimensioning/unit changes will be required. They are to numerous to list here. This effort will require a detailed review of each Traffic related section.

CHAPTER SEVEN

Maintenance

The following is given as a guide to the conversion of Maintenance activities to the metric system and can be used as guidance in the conversion.

MAINTENANCE MANAGEMENT SYSTEM DATABASE

- CDOT Form 909 (green Sheet) will accommodate metric maintenance data reporting now. The computer program for reports must be rewritten to accommodate metric.
- The MMS program must convert to metric before the designated conversion date and contain the proper CDOT-established parameters.
- The conversion to Metric must occur at or before the start of a Fiscal Year.
- All Historical Data will stay as is, and a computer program must be written to convert the data so that historical data will be reported in metric form.

MAINTENANCE MANAGEMENT SYSTEM ACTIVITIES UNITS

- All Units of accomplishments, and Material Quantities must be converted to the metric conversion units and quantities established by CDOT.

Quantity	Unit	Symbol
length	millimeter meter kilometer	mm m km
area	square meter square kilometer hectare	m^2 km^2 ha
volume	liter cubic meter	L m^3
mass	metric ton	Metric Ton

Manuals

- The Maintenance Management System Manual must be converted to metric.
- The Manual of Maintenance Procedure must be converted to metric.

Maintenance

Maintenance in the field should have no major problems in converting to metric. The following is a list of items that must be addressed:

- Training of field personnel.
- The changing of all signs.
- Mile points to reference points.
- Copies of manual use now in the field to metric.

Oversize Permits Extra-Legal Vehicles or Loads (Trucking Industry)

The following is a brief listing of items which must be changed as a result of the metric conversion:

- The rules and regulations pertaining to transport permits for the movement of extra-legal vehicles or loads, 2 CCR 601-9.
- The Bridge Weight Limit Map.
- The Colorado Pilot Car Escort and Oversize Restriction Map.
- The Height Restriction Map.
- The rules and regulations pertaining to longer vehicle combinations.
- All permit-related DOT forms: DOT 51, 52, 59, 72, 74, 75, 79, 100, 729, 865, 934, and 1085.
- The For Your Information (FYI) Pamphlets.
- All Colorado Revised Statutes, in particular 42-4-401 through 42-4-409.

Oversize Permits Extra-Legal Vehicles or Loads (Trucking Industry) (Cont'd)

Other items which would require amendments, but which are not under Staff Maintenance's authority include:

- All signing for:

    - Height clearance on bridges

    - Load posted structures

- The Vertical Clearance Report

ROAD EQUIPMENT AND SHOPS

Equipment Management System (EMS)

- All current vehicles, including cars and trucks, contain a speedometer and odometer on which miles are the base unit of measurement. As the nation goes metric, so will the speedometers and odometers that come with the new vehicles. We must program in the ability to track usage from some meters measuring miles and other meters measuring kilometers.

- Currently all fuel is purchased in gallons. During the transition period we will need to know, for each fuel purchase, the unit of measure used (gallons or liters) and the number of units purchased. Some special computer programming and some forms changes must be done to accommodate this.

- Some fields in the main inventory table of the equipment database contain data that is the result of the current system of measurement. Some examples are:

    Capacity = 32,500 lbs.

    GVW, capacity = 2 & 1/2 Cubic Yards

    Engine displacement = 466 CID.

    All of these fields are descriptive only and must be changed (possibly with mass updates).

ROAD EQUIPMENT AND SHOPS (Cont'd)

Equipment Repair Shops

- The shops have already been impacted by the metric system of measurement and have some tools to accommodate both standard and metric sizes of nuts and bolts. They are in some instances also stocking both standard and metric sizes of nuts and bolts.

- Some precision measuring tools may need to be purchased that are calibrated in metric units of measure. These include but are not limited to: micrometers, vernier calipers, feeler gauges, dial gauges, pressure gauges, thermometers, torque wrenches, etc.

- Some decisions must be made on the need for replacing other tools.

Equipment Specifications

- Currently all major equipment manufacturers are listing both the English units of measurement and metric units of measurement in all of their printed literature. Little effort will be required to change CDOT equipment bid specifications.

- Changes made by the manufacturers because of a different system of measurement are of more concern. For example:

  Currently we are buying snow plows that are 12 feet wide with replaceable cutting edges that are 6 feet long and have bolt holes 6 inches apart. If the industry changes the width to a round number on either side of 3657.6 mm. with a different bolt hole spacing than 152.4 mm., we must then either rebuild all old plows to the new size and hole spacing, or order and stock both sizes of plow blades.

CHAPTER EIGHT

Planning

UNITS

Quantity	Unit	Symbol
length	millimeter meter kilometer	mm m km
area	square millimeter square meter	mm^2 m^2
mass	gram kilogram metric ton	g kg Metric Ton
temperature	degree Celsius	°C

PLANNING

Overall, the planning unit will be reactive to other units.

- Future Transportation Plans must reflect metric units.
- Data requested by the unit must be provided in metric.
- No past plans will be converted to metric.

PAVEMENT MANAGEMENT PROGRAM

- All future software must handle metric units.
- The process of converting measurements such as International Roughness Index (IRI) and rut depth from metric to English units, will be discontinued.

INTERMODAL

- All databases must be established in metric units.
- Any other existing data must be converted by the hard conversion convention.

GIS

- The ARCINFO software will continue to be run with metric units.

TRAFFIC

- Figures the Traffic unit is responsible for will be unaffected by the conversion to metric.
- The database "section termini" must be converted to read "reference point" rather than "milepoint".

FIELD

- The Distance Measuring Instruments (DMI) must be recalibrated to metric, and metric tape must be purchased for all field personnel.

DATA MANAGEMENT

- The Integrated Roadway Information System (IRIS) database must be converted to metric with the assistance of Information Systems personnel (This will be mostly technical in nature, as the conversion will nearly all be performed as per the hard conversion conventions).
- Records with descriptions indicating state highway mileposts, which will be converted to reference points must be converted to metric.
- New software must be acquired from FHWA so that all reports submitted to them will be in metric units.

The consensus amongst personnel in DTD is that the preferred course of action regarding existing mileposts is that they remain and be converted to reference points. Removing them in favor of kilometer posts would essentially result in recreating all databases to reflect the new kilometer posts. This would create an inordinate amount of work for the GIS, Traffic, Pavement Management and Data Management units, all of which keep their own databases.

CHAPTER NINE

Environmental

The Office of Environmental Services (OES) will complete the metrication of the Branch through the combined efforts of the Unit Supervisors and the metric conversion coordinator.

UNITS

Quantity	Unit	Symbol
length	millimeter meter kilometer	mm m km
area	square meter square kilometer hectare	m^2 km^2 ha
volume	liter cubic meter	L m^3
volume rate of flow	cubic meter/second liter/second	m^3/s L/s
mass	milligram kilogram	mg kg

NOISE ANALYSIS AND LEAKING UNDERGROUND STORAGE TANK REMEDIATION

Noise Analysis Program

- After April 1993, all field measurements must be in both metric and English units.
- Noise manual tables and graphs must be converted to metric units during future use. This must be done by the office that is the primary source of these tables and graphs.
- Computer programs used to analyze and predict traffic noise levels must accept metric units as well as English units.
- Noise barrier panels should be dimensioned in metric units with English equivalents shown in parenthesis.
- Traffic noise sound levels must be reported in units called "A-weighted decibels" shown as dB(A). This unit represents the sound from highway traffic noise "weighted" to reflect noise levels as perceived by the human ear. This unit is used worldwide. Metric units will be used in technical reports or research.
- The Noise Abatement Guidelines must be revised to include metric units. The extent of these changes are limited to approximately four distance-related references. The updating of referenced publications and federal regulations will be the responsibility of the publisher.

Leaking Underground Storage Tank (LUST) Remediation Program

- After June 1993, all field measurements must be in both metric and English units.
- Contaminate levels must be recorded in metric units and expressed in parts per million (ppm) or parts per billion (ppb).
- Detailed Site Investigation forms must be changed to show metric and English units.
- Corrective Action Plans (CAP) must be changed to show metric and English units.
- Computer programs used to compile and analyze storage tank data must accept metric data.

ARCHAEOLOGY UNIT AND PALEONTOLOGY

- All field measurements must be recorded in metric units.
- Project site location information must be recorded in measurements reflecting the reference point units that comply with future CDOT policy.
- Future maps, sketches and photographs and their scales must be shown in metric units.
- Future transportation project reports must show both units of measurement and English will be discussed for the general audience. The metric unit must be shown first in these reports with the English units in parenthesis.

AIR QUALITY UNIT

- Future field measurements for line source data, (highways, intersections, etc.) must be recorded in metric or converted to metric units and also show English units.
- Data input files for computer programs used to analyze air quality use a mixture of English and metric units. The output/results must be expressed in metric units.
- Air quality information for CDOT highway projects must be presented in language that is understandable by the general public.

HAZARDOUS WASTE UNIT

- Contaminate levels must be measured and reported in metric units. Contaminates in pure water samples must be measured in (ppm) = milligrams per liter, etc. Contaminates in soil or sludge samples must be measured in (ppm) = milligrams per kilogram, etc.
- CDOT hazardous waste reporting forms must be revised for metric conversions. The Initial Site Assessment (ISA) checklist must also be revised. ISA sketch maps for locations must show a metric and English scale for distances.
- Preliminary Site Investigation (PSI) reporting forms must be revised. PSI checklists are commonly provided by the consultants doing the work. All PSI forms as well as location maps, field logs and project narratives must be revised to show metric and English notation. Laboratory results must be given in metric units.
- Hazardous waste issues must be discussed in documents and public meetings in metric units and also English units, as English units are usually more familiar to the audience.

BIOLOGY AND ECOLOGY

- Field measurements, plans and maps must be dimensioned in both metric and English units.

- Areas must be converted to square meters or hectares, but will also show English units.

- Stream flows and volumes must be given metric units with English units in parenthesis.

- Wildlife resource mitigation including fences, crossing structures, lighting, reflector spacing and boulder size must be dimensioned in metric units along with the English equivalents.

- Units of measurement described in some regulatory documents must be converted to metric units at the time of application and will be discussed in narrative in metric and English units.

HISTORY AND SCENIC BYWAYS

- Conversion from miles and mileposts to metric units is very important to this program. This conversion must be coordinated with other CDOT offices assigned the conversion responsibilities.

- Distance measurements must be shown in metric with English units in parenthesis.

- Areas must be converted to square meters or hectares with English units in parenthesis.

MISCELLANEOUS ENVIRONMENTAL SERVICES

- The Geographic Information System (GIS) environmental base information must be programmed in metric units. All distance measurements will reflect metric units. This information will be available to CDOT Region staff and others.

- All project clearances must be reported in metric units.

- Section 4(f) and 6(f) Evaluations must describe impacts to protected resources in metric and English measurements and all maps and photographs must be on metric and English scales.

COORDINATING THE CONVERSION PROCESS

- In order to complete the Branch conversion to a metric program, OES must evaluate the influence of federal agencies that direct our activities, all agencies that coordinate with our activities and those that are influenced by our activities.

- All Branches will need to review the legislation that affects their office operations.

- In the Office of Environmental Services each unit supervisor as well as each environmental specialist must convert regulatory guidelines and directive material to metric units at the time it is needed and wherever necessary to comply with the CDOT objective to convert to metric units.

- Many state agencies that coordinate project activities with us, cooperate in joint agreements, or review our documents will probably not start using metric language until the federally supported state agencies have completed their conversion process. The CDOT metric conversion decisions and timetables must be communicated to the state agencies as early as possible. Also, both English and metric measurements must be shown in technical reports, coordination letters and in environmental documents to reduce the number of problems experienced during CDOT's conversion to the metric system.

- The metric literacy of the public audience must be considered whenever environmental documents are developed and public meetings convened. Both metric and English units must be shown and presented or the conversions are explained at the time the units are discussed.

TRAINING AND INTERNAL COORDINATION

- One general branch training session must be held during the early part of the conversion effort in order to discuss procedures and schedules for completing the metric conversion process for the branch.

- Each staff member must be provided a metric conversion table or an electronic conversion option.

- OES members must become familiar with the metric units used throughout CDOT as they are made available through the CDOT Metric Conversion Committee.

- There must be a continued coordination effort throughout CDOT. The OES staff must be aware of the conversion progress in other offices to enable them to assist in completing Department manuals, guides, etc. for which OES shares ownership. Also, it is important to be aware of completed conversions that can be incorporated into OES project development work.

- OES has identified fourteen CDOT directives that need either revisions or replacement and metric conversion consideration must be given to each.

ARCHAEOLOGY UNIT AND PALEONTOLOGY

- All field measurements must be recorded in metric units.
- Project site location information must be recorded in measurements reflecting the reference point units that comply with future CDOT policy.
- Future maps, sketches and photographs and their scales must be shown in metric units.
- Future transportation project reports must show both units of measurement and English will be discussed for the general audience. The metric unit must be shown first in these reports with the English units in parenthesis.

AIR QUALITY UNIT

- Future field measurements for line source data, (highways, intersections, etc.) must be recorded in metric or converted to metric units and also show English units.
- Data input files for computer programs used to analyze air quality use a mixture of English and metric units. The output/results must be expressed in metric units.
- Air quality information for CDOT highway projects must be presented in language that is understandable by the general public.

HAZARDOUS WASTE UNIT

- Contaminate levels must be measured and reported in metric units. Contaminates in pure water samples must be measured in (ppm) = milligrams per liter, etc. Contaminates in soil or sludge samples must be measured in (ppm) = milligrams per kilogram, etc.
- CDOT hazardous waste reporting forms must be revised for metric conversions. The Initial Site Assessment (ISA) checklist must also be revised. ISA sketch maps for locations must show a metric and English scale for distances.
- Preliminary Site Investigation (PSI) reporting forms must be revised. PSI checklists are commonly provided by the consultants doing the work. All PSI forms as well as location maps, field logs and project narratives must be revised to show metric and English notations. Laboratory results must be given in metric units.
- Hazardous waste issues must be discussed in documents and public meetings in metric units and also English units, as English units are usually more familiar to the audience.

CHAPTER TEN

Computer Systems

This chapter covers all standard programs used excluding specialized traffic and bridge programs. The expertise to review those packages is within their respective branches.

By and large the impact of a conversion to metric in our computer applications is very minimal. The majority of the systems are already capable of working in metric simply by hitting a default switch in the program set-up. The primary problem will be the loading of metric standards tables to replace the existing English tables. This will take some time and needs to be placed in the department's schedule for conversion.

There are a few problems associated with a conversion to metric:

- Most notably, neither the Hydrain or WSPro programs used by Hydraulics will work in metric. Perhaps this will require new applications or maybe they can use these applications with soft conversions. Some research in this area will be necessary.

- The BAMS-DSS Module also poses a problem, as it is a historical database dependent on the units used in the past, in this case English. Some brainstorming will be required here to determine the best solution. Since BAMS is an AASHTO sponsored product, it is felt that the AASHTO task force in charge of BAMS should be responsible for this.

- The last problem that we foresee is with COGO and the R.O.W. applications. Actually, the problem is not with the software, rather with the industry standard in providing legal descriptions. It is not certain what influence the Transportation industry will have on the legal and Real Estate businesses. We might be required to maintain an English version of COGO to provide legal information.

- The conversion to metric may require us to determine new standards for significant figures in calculations. For example, if linear measurements are kept to the hundredths, the accuracy between feet and meters could be significant. This needs to be explored.

COMPUTER GEOMETRY (COGO)

The CDOT COGO program will easily accept metric figures, however:

- Many of the interfaces we have prepared for integrating COGO with MOSS and RoadCalc, for example, are evidently unit dependent. It has been estimated that approximately 25% of the internal code will need to be reviewed and perhaps revised to facilitate interfaces and the metric print-out of information.

- A potential area of concern is the changes the department may wish to make to legal descriptions. Will the legal and Real Estate market be forced to switch as well or will their lobbying pressure force us to reach a compromise. This needs to be reviewed.

- Overall, COGO is ready for metric testing.

GRAPHICS

AutoCAD and Series 5000

Both AutoCAD and Series 5000 do have settings internal to the programs to reflect both metric and English, and the conversion would require just a few keystrokes. Since neither AutoCAD or Series 5000 have any tables, there is no impact here.

The only problems foreseen in the Graphics area is the number of user prepared "Macros" and the "Standards" drawings that have been created. The users may need to evaluate their applications and depending on the severity of the problem and the necessity of the application, IS help may be necessary. The plan to convert standards should consider AutoCAD drawing time to properly reflect the impact.

PICS

PICS (Project Item Coding System) in a sense is two applications in one. Part of PICS is AutoCAD graphics tools. The majority of these are not unit dependent and will require little effort to be converted to metric. The second part is a coordinate and item description based database. Currently it is only used during the project life and as such will not be affected by a conversion to metric. If some PICS files are historically recorded prior to the conversion, some soft conversion will be necessary and a simple conversion program may be necessitated.

- Many specific Macros and subroutines that hinge on the drafting standards must be corrected. Once the drafting standards are identified this will require as much as six months to fix.

- Some minor changes to fonts and symbols are required.

- A File header identifying the files as English or metric needs to be added.

ENGINEERING

MOSS And RoadCalc

We are moving right into the strengths of these products by converting to metric. In fact some problems we have encountered with MOSS will be eliminated, most particularly the problems with significant figures in coordinates. MOSS always had problems going over 10,000 feet in elevation. Both products are being used by Ministries of Transportation in Canada with good success.

Extreme caution will be required to convert the standards tables (i.e. superelevation, etc.) to assure we design using correct information. Many tables and related checks are internal to these programs.

MOSS

- All Macros, UPM's, Input files and macros, and linesymbol files will need to be reviewed and modified as appropriate.
- Regions will need to be notified of changes and will need to review and modify their own Macros/UPM's as appropriate.
- Some minor fixes on internal fonts and symbols will be required.
- Design standards will need to be incorporated.

RoadCalc

- Design standards will need to be incorporated.

HYDRAULICS

HEC2, which is the major Hydraulics program, is already equipped for metric data. However, we are not so fortunate with the Hydrain and WSPro applications. Evidently, neither of these programs will operate in the metric environment. They are very dependent on English nomographs. Two solutions are evident for these programs:

- Continue to use them, with hydraulic engineers making soft conversions back and forth. This may be best until the piping industry manufactures everything in metric.
- Purchase new programs that accomplish the same task in metric. In fact, maybe both of our programs will be rewritten to meet new user demands.

This is an area that will require additional research and effort to determine the best solution.

MANAGEMENT SYSTEMS

PSTS And BAMS

The actual operation of these programs is not unit dependent and therefore will require no changes. However, the Item Codes and Tables are currently recorded using English. All of these tables will need to be reentered using metric units. For BAMS, the problem that will be encountered is with the historical module DSS. Some scheduling calculations in PSTS are based on centerline miles and will need to be changed, although this problem should be easy to correct.

BAMS

- There are over 4,000 items to convert to create a metric Items List (NOTE: Standards and specifications must be changed first).
- Item descriptions that are in our control must be changed (e.g. 0.2 Meter Concrete Pavement).
- Other Item descriptions must be changed as industry makes the changes (e.g. 0.5 meter CSP).
- Must have a development area that users cannot purposely or accidentally access (Cannot use the existing development environment because CASpc is currently dependent upon it).
- Must test Metric-BAMS with an existing project that has a diversity of items (Estimates and data will be in both English and metric).
- Phase 1 of the Items List change must be made for appropriate items on the test project. The data must be created in PES and transferred to LAS and then to CAS/CASpc for testing of contractor payments.
- The common-unit conversion within DSS must be modified for metric calculations (CDOT has the option of waiting on this issue until AASHTO and the BAMS Task Force make a determination and recommendation).
- InfoTech must have an overview report to the BAMS Task Force for review and inclusion into the 94/95 BAMS Work plan. Meanwhile, CDOT has three options:

  1) Make changes ourselves as reflected above.

  2) Wait for InfoTech to make the changes (94/95).

  3) Since Bob Clevenger is the Chairman of the AASHTO Task Force on Metric Conversion, see if he can apply pressure through AASHTO to get the BAMS Task Force to move quicker on this issue.

OTHER SYSTEMS

GIS

The GIS (Geographic Information System) is currently managed by the Division of Transportation Development. They indicate that there will be no impact moving to metric. It probably will require some lead time to assure data can be retrieved using a metric coordinate base.

- DTD must be contacted to determine the actual impact and time requirements.

IRIS

IRIS (Integrated Roadway Inventory System) is a roadway database based on mileposts. Currently it is comprised of four modules:

Crashes	Historical databases of accidents. Initial information comes from DMV.
Structures	Database of all structures locations and conditions.
Roadway Characteristics	List of traffic volumes, roadway geometry, etc.
Maintainable Items	Uploads of the MMS data used by maintenance.

The structures database is based on a higher degree of accuracy but is still dependent on the mileposts. Some planning will be necessary to determine how to most accurately convert away from milepost based data.

General References

The following references were used in preparation of this manual and/or are available as aids to a metric conversion.

METRIC CONSTRUCTION GUIDES

American Society for Testing and Materials (1916 Race Street, Philadelphia, PA 19103, Phone: (215) 299-5585):

- *ASTM E621, Standard Practice for the Use of Metric (SI) Units in Building Design and Construction, 1984.* 37 pp. 1984. $12.00.

National Institute of Building Sciences (Publications Department, 1201 L Street N.W., Suite 400, Washington, DC 20005, Phone: (202) 289-7800):

- *The Metric Guide for Federal Construction,* 1st Edition, Operating Committee of the Interagency Council on Metric Policy, National Institute of Building Sciences (NIBS), Washington, DC, 1991. Written by NIBS specifically for the construction industry and reviewed by metric experts throughout the country. Includes background on the federal metric laws; facts on metric in construction; an introduction to metric units; a primer on metric usage for architects, engineers, and the trades; requirements for metric drawings and specifications; guidance on metric management and training; and a list of current metric construction references. 34 pp. $15.00 (including shipping and handling).

- *GSA Metric Design Guide.* Interim design guide developed by the General Services Administration (GSA) for use by federal project managers and their A/Es. Contains practical architectural, civil, structural, mechanical, and electrical design information; a list of available "hard" metric products; sample drawings; and related reference information. 77 pp. $8.00; $5.00 if ordered with the above *Metric Guide for Federal Construction.*

National Technical Information Service (5285 Port Royal Rd., Springfield, VA 22161, Phone: (703) 487-4600).

- NBS Technical Note 990, *The Selection of Preferred Metric Values for Design and Construction.* H.J. Milton, author. 75 pp.

GENERAL METRIC INFORMATION

American Association of State and Highway Transportation Officials (444 N. Capital St., N.W., Suite 225, Washington DC 20001; Phone (202) 624-5800):

- *Guide to Metric Conversion.*

American National Metric Council (4330 East-West Highway, Suite 1117, Bethesda, MD 20814-4408; Phone: (301) 718-6508 for publications):

- *ANMC Metric Editorial Guide.* $5.00.
- *SI Metric Training Guide.* $5.00.
- *Metrication for the Manager.* $15.00.

National Technical Information Service (5285 Port Royal Rd., Springfield, VA 22161; Phone: (703) 487-4600):

- PB 89-226922, *Metric Handbook for Federal Officials* (includes Federal Standard No. 376A of May 5, 1983, *Preferred Metric Units for General Use by the Federal Government).* 45 pp. 1989. $17.00.

U.S. Government Printing Office (Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402; Phone: (202) 783-3238):

- NIST Special Publication 330, 1991 Edition, *The International System of Units (SI).* 56 pp. August, 1991. $3.50.
- NIST Special Publication 811, *Guide for the Use of the International System of Units.* Arthur O. McCoubrey, author. 34 pp. September, 1991. $2.50.
- "Metric System of Measurement: Interpretation of the International System of Units for the United States; Notice. *Federal Register,* December 20, 1990.

U.S. Metric Association (10245 Andasol Ave., Northridge, CA 91325; Phone: (818) 363-5606):

- *Style Guide to the Use of the Metric System.* $3.00; bulk discounts available.
- *SI Metric Style Guide for Written and Computer Usage.* $2.00; bulk discounts available.
- *Freeman Training/Education Metric Materials List.* $38.00.
- *Metric Vendor List.* $28.00.

STANDARDS & SPECIFICATIONS

American Association of State and Highway Transportation Officials (444 N. Capital St., N.W., Suite 225, Washington DC 20001; Phone (202) 624-5800):

- *Standard Specifications for Transportation Materials.* Two-volume set. Includes dual units. $115.00.

American National Standards Institute, Inc. (11 West 42nd St., New York, NY 10036; Phone: (212) 642-4900):

- ANSI/IEEE 268, *American National Standard Metric Practice.* 48 pp. 1982. $23.00.

American Society for Testing and Materials (1916 Race St., Philadelphia, PA 19103; Phone: (215) 299-5585):

- ASTM E380, *Standard Practice for Use of the International System of Units (SI).* 35 pp. 1992. $23.00.

CIVIL

American Congress on Surveying and Mapping (5411 Grosvenor Lane, Suite 100, Bethesda, MD 20814; Phone (301) 493-0200):

- *Metric Practice Guide for Surveying and Mapping.* 11 pp. 1978. $10.00.

American National Metric Council (4330 East-West Highway, Suite 1117, Bethesda, MD 20814-4408; Phone: (301) 718-6508 for publications):

- *ANMC Metric Editorial Guide.* Fourth edition. 16 pp. 1990. $2.00.
- *SI Metric Training Guide.* 17 pp. 1991.
- *Metric Guide for Educational Materials.* 22 pp. 1977.
- *Managing Metrication in Business and Industry.* 203 pp. 1976.

STEEL

American Institute of Steel Construction (Metric Publications, One E. Wacker Dr., Suite 3100, Chicago, IL 60601-2001; Phone: (312) 670-5414):

- *Metric Properties of Structural Shapes with Dimensions According to ASTM A6M.* Metric version of Part I of the *Manual of Steel Construction.* $10.00.

- *Manual of Steel Construction, Metric Edition.* To be published in 1994.

Industrial Fasteners Institute (1105 East Ohio Building, 1717 E. 9th St., Cleveland, OH 44114; Phone: (216) 241-1482):

- *Metric Fastener Standards.* $60.00.

STRUCTURES

Florida Wire and Cable Company (P. O. Box 6835, Jacksonville, FL 32236, Phone: (800) 874-0093).

- *Physical Properties of Strand, Uncoated, Stress Relieved for Prestressed Concrete Structures.*

Ralph E. Anderson, Chief of Bridges and Structures, Illinois Department of Transportation.

- *Memorandum on Metric Conversions.* March 1, 1993

MEASURING INSTRUMENTS

Stanley Tools (800) 262-2161, **Lufkin** (912) 362-7511, or **U.S. Tape** (703) 256-1500.

- *Dual Unit Tape Measures.*

Staedtler-Mars (Model 987-18-1), **Alvin** (Model 117 PM), and **Charvoz** (Model 30-1261).

- *Metric Scales and Templates.*

American Standard (Call Ms. Barbara Munson at (703) 841-9585).

- *Metric plumbing templates.*

Sharp Instrument Company (Van Schaack Premium Group, 4747 W. Peterson, Chicago, IL 60646; Phone: (312) 736-5600):

- *Sharp Model EL-344G Metric Calculator.* Converts linear dimensions, areas, volumes, liquids, pressures, and masses with two keystrokes. Very handy for simple conversions. Under $20.00.

Radio Shack

- *Metric Calculator (catalog #65-931).* Hand-held metric conversion calculator.

Texas Instruments

- *TI-1895II Metric Calculator.* Hand-held solar calculator with 40 metric conversion functions.

Timesaver Templates (13240 Valley Branch, Dallas, TX 75381):

- *Metric templates.*

Empire Berol USA (105 Westpark Drive, P.O. Box 2248, Brentwood, TN 37024):

- *Metric templates.*

Chartpak/Pickett (1 River Road, Leeds, MA 01053):

- *Metric templates.*

Forestry Suppliers, Inc. [Mail-order company with free catalog - 532 pages] (P.O. Box 8397, Jackson, MS 39284-8397; Phone: 1-800-647-5368):

- *Metric Frisco Rods*
- *Metric Philadelphia Rods*
- *Micrometer Targets*
- *Much More!*

FED. ROAD REGION	DIVISION	PROJ. NO.	SHEET NO.
VIII	COLO.	BRS-PLH-CXBRS 0145(16)	1

AS CONSTRUCTED

NO REVISIONS ☐ REVISED ☐ VOID ☐

REVISIONS

COLORADO DEPARTMENT OF TRANSPORTATION

PLAN AND PROFILE OF PROPOSED
FEDERAL AID PROJECT NO. BRS-PLH-CXBRS 0145(16)
STATE HIGHWAY NO. 145
MONTEZUMA COUNTY

SCALES OF ORIGINAL DRAWINGS

ON PLAN: 1:1000

ON PROFILE: 1:1000 HORIZ.
1:10 VERTICAL

GRADE LINE ON PROFILE IS SHOWN AS GRADE OF FINISHED ROAD

TABULATION OF LENGTH AND DESIGN DATA

STATION	Meters ROADWAY SH 145	*FH 60	MAJOR STR.
STA. 2+956.56 BEGIN BRS-PLH-CXBRS 0145(16)= STA. 31+895.49 ON S 0153(14)			
	465.372		
STA. 3+421.932 BEGIN MAJOR STR. NO. N-03-F			
			40.612
STA. 3+462.544 END MAJOR STR. NO. N-03-F			
	289.545		
STA. 3+752.088 END BRS-PLH-CXBRS 0145(16)= STA. 31+099.963 ON S 0153(12)			
STA. 0+124.705 BEGIN F.H. 60			
		728.734	
STA. 0+853.439 END F.H.60= STA. 0+853.439 ON F.H. 60-1(3)			
TOTAL	754.917	728.734	40.612

SUMMARY	Meters	Kilometers
ROADWAY (NET LENGTH)	754.917	0.755
MAJOR STRUCTURE	40.612	0.0406
PROJECT GROSS LENGTH	795.529	0.7955

	S.H. 145	F.H. 60
MAXIMUM RADIUS OF CURVE	370 m	85 m
MAXIMUM GRADE	1.4571%	6.5%
MINIMUM S.S.D. HORIZONTAL	> 152 m	44 m
MINIMUM S.S.D. VERTICAL	245 m	122 m
MAXIMUM DESIGN SPEED	88 Km/h	40 Km/h
2012 DESIGN TRAFFIC	DHV = 270 ADT = 1 350	DHV = 70 ADT = 350
DHV TRUCKS %	7%	--
CLEAR ZONE DISTANCE (TANGENT)	5.48 m	2.1 m
CLEAR ZONE DISTANCE (370 m RADIUS)	7.6 m	

* FOR INFORMATION ONLY

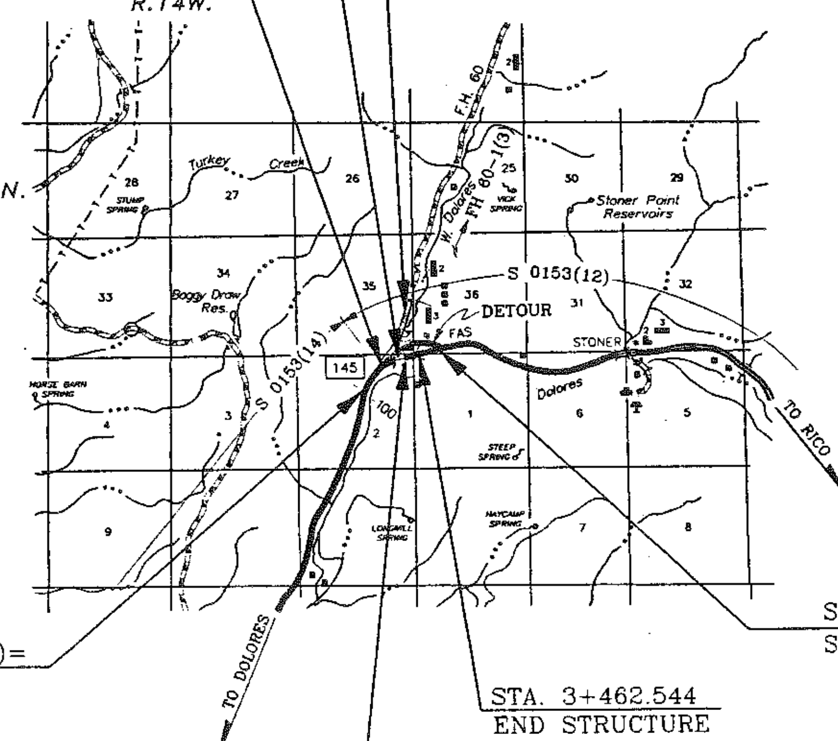
DISCLAIMER

NOTE: THE FOLLOWING EXAMPLE PLANS ARE A PRELIMINARY GUIDE FOR METRIC CONVERSION AND ARE NOT TO BE CONSTRUED AS FINAL.

EXISTING STRUCTURE
NO. N-03-G

STA. 0+124.705 BEG. F.H. 60

STA. 0+853.439 END F.H. 60 =
STA. 0+853.439 ON F.H. 60-1(3)



STA. 2+956.56 BEGIN BRS-PLH-CXBRS 0145(16)=
STA. 31+895.49 ON S 0153(14)

STA. 3+752.088 END BRS-PLH-CXBRS 0145(16)=
STA. 31+099.963 ON S 0153(12)

STA. 3+462.544
END STRUCTURE
NO. N-03-F

STA. 3+421.932
BEGIN STRUCTURE
NO. N-03-F

0 1220 2440 3660
ORIGINAL SCALE: 25.42mm = 1220m

SHEET NO.	INDEX OF SHEETS
1	TITLE SHEET
2	STANDARD PLANS LIST
3-4	TYPICAL SECTIONS AND DETAILS OF PARKING AREA, GUARD RAIL WIDENING ON S.H. 145, AND WATERWAY IN CUT
5	GENERAL NOTES, AND ROADWAY SEEDING PLAN
6-8	SUMMARY OF APPROXIMATE QUANTITIES
9	STRUCTURE QUANTITIES
10	SUMMARY OF EARTHWORK AND TABULATION OF BASE COURSE AND SURFACING
11	INTERSECTION DETAILS
12-13	WETLAND AND EROSION CONTROL PLAN
14	TEMPORARY WATER DIVERSION PLAN
15	CHANNEL DETAILS
16-17	S.H. 145 PLAN AND PROFILE
18-19	TABULATIONS OF SIGNS
20	SIGNING AND STRIPING PLAN

NEW AND REVISED STANDARDS

M-203-1	APPROACH ROADS	(1 SHEET)
M-609-1	CURBS AND GUTTERS	(1 SHEET)
S-612-1	TYPICAL DELINEATOR INSTALLATIONS	(SHEET 5)
S-614-2	CLASS 1 GROUND SIGN INSTALLATIONS	(1 SHEET)
S-614-10	TYPICAL MARKER ASSEMBLY INSTALLATIONS	(1 SHEET)
S-614-12	STRUCTURE NUMBER INSTALLATION	(1 SHEET)
S-630-1	TRAFFIC CONTROLS FOR HIGHWAY CONSTRUCTION	(9 SHEETS)

AS CONSTRUCTED INFORMATION

CONTRACTOR______

______ ENGINEER______
(Project or Resident)

PROJECT STARTED______

PROJECT COMPLETED______

AS CONSTRUCTED PLANS APPROVED______

TITLE DATE

C.D.L./REGION 5

01/25/94 D:\METRIC\TDOLL.DWG 89080 H101

AS CONSTRUCTED		
NO REVISIONS:	REVISED:	VOID:

FED. ROAD REGION	DIVISION	PROJ. NO.	SHEET NO.
VIII	COLO.	BRS-PLH-CXBRS 0145(16)	2

THE STANDARD PLAN SHEETS INDICATED HEREON BY A MARKED BOX ARE TO BE USED TO CONSTRUCT THIS PROJECT.

DEPARTMENT OF HIGHWAYS
STATE OF COLORADO
DIVISION OF HIGHWAYS

STANDARD PLANS LIST

M & S STANDARDS — JANUARY, 1982

10/29/92 LA_PLATA:::(USER/89080/ACAD) BRS_LIST.DWG 89080 H101

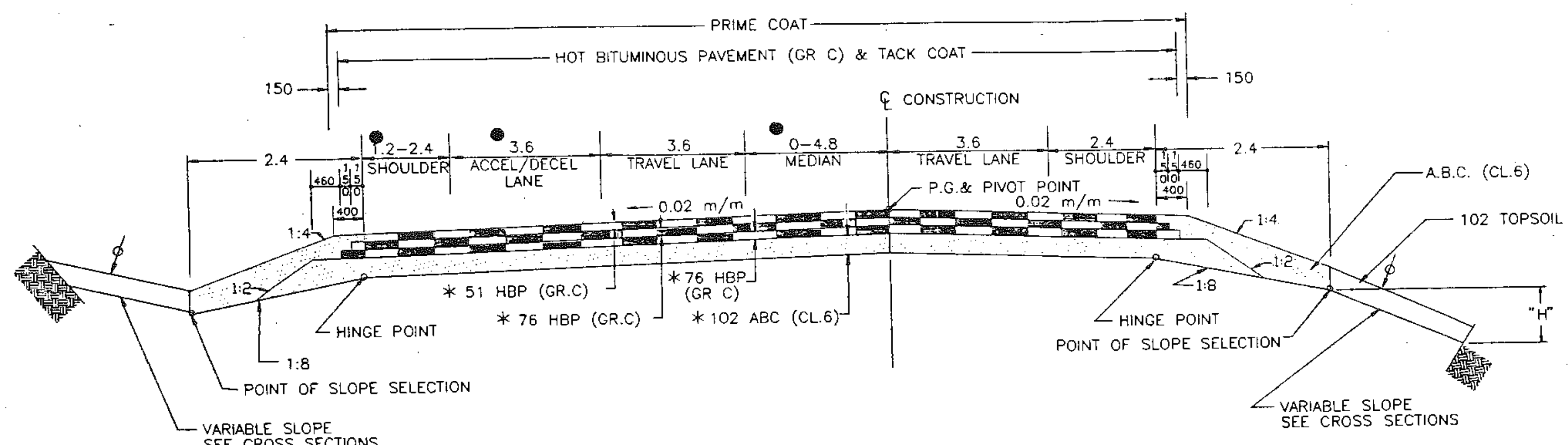
AS CONSTRUCTED		
NO REVS.	REVISED	VOID

FED. ROAD REGION	DIVISION	PROJ. NO.	SHEET NO.
VIII	COLO.	BRS-PLH-CXBRS 0145(16)	3

NOTE: WHOLE NUMBERS INDICATE MILLIMETERS
DECIMAL NUMBERS INDICATE METERS.

TYPICAL SECTION "A" S.H. "145

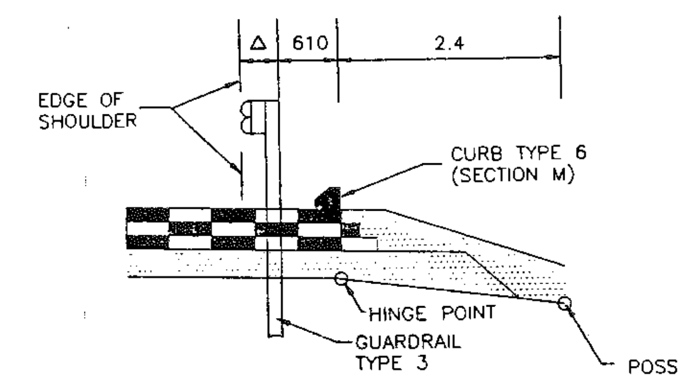
STA. 2+956.56 TO STA. 3+421.932 AND STA. 3+462.543 TO STA. 3+752.089
STA. 3+421.932 TO STA. 3+462.544 (SEE BRIDGE PLANS)



● SEE INTERSECTION DETAILS FOR WIDTHS AND LOCATIONS

DETAIL OF GUARDRAIL WIDENING ON SH 145

△ 450 FOR WOODEN POSTS
390 FOR STEEL POSTS



THE CONTRACTOR WILL BE REQUIRED TO PLACE TOPSOIL TO THIS LINE AFTER COMPLETION OF PAVING OPERATION.

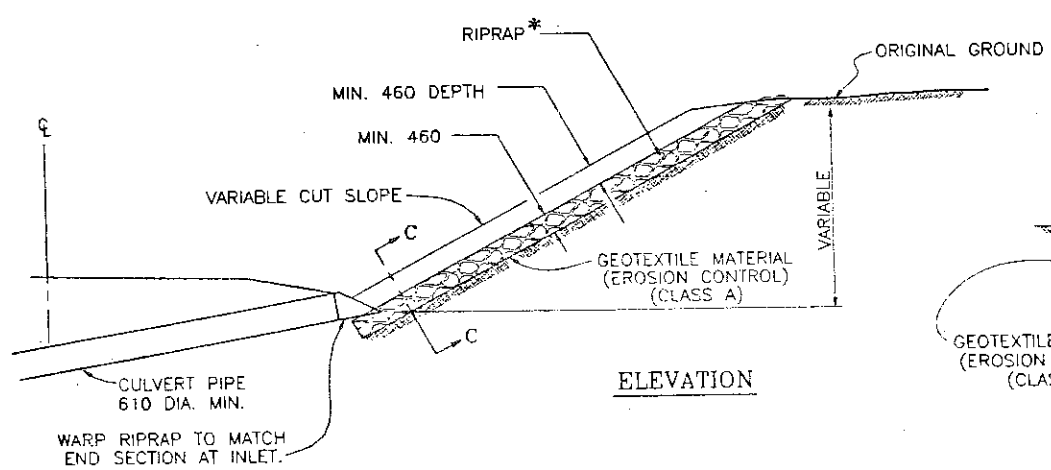
* APPROXIMATE THICKNESS

NOTE: THE DEPTH AND WIDTH OF THE SIDE DITCH SHALL BE VARIED WHERE NECESSARY IN ORDER TO PROVIDE PROPER DRAINAGE.

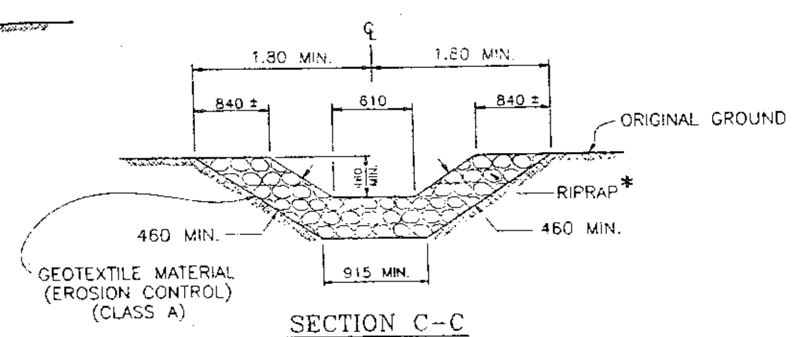
FILL SLOPES

SLOPE 1:4 WHERE "H" IS LESS THAN 4.6
SLOPE 1:2 WHERE "H" IS OVER 4.6
IN SPECIAL CASES, SLOPE MAYH BE STEEPENED

BREAK POINTS ON SLOPES AND IN BOTTOMS OF DITCHES SHALL BE ROUNDED DURING CONSTRUCTION FOR A PLEASING APPEARANCE.



ELEVATION



SECTION C–C

WATERWAY IN CUT

FH 60 STA. 0+649.229 & 0+713.232

*RIPRAP STONE SIZE 230

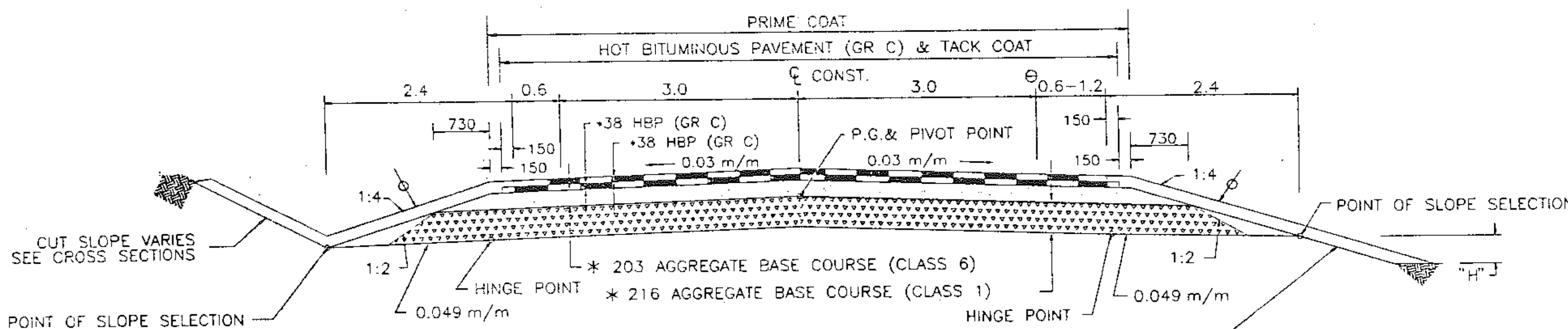
1/01/93 Lo..Plots:(USLN/89080/ACAD) FORESTS.DWG 89080 11101 Lee

AS CONSTRUCTED		
NO REVISIONS	REVISED	VOID

FED. ROAD REGION	DIVISION	PROJ. NO.	SHEET NO.
[illegible]	COLO.	BRS-PLH-CXBRS 0145(16)	4

NOTE: WHOLE NUMBERS INDICATE MILLIMETERS
DECIMAL NUMBERS INDICATE METERS

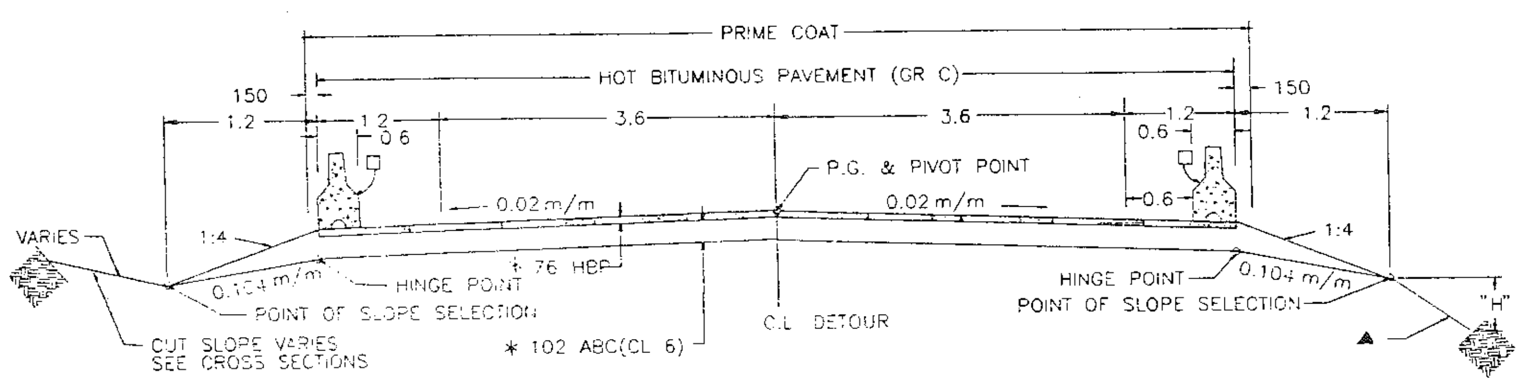
TYPICAL SECTION "B" FOREST HWY. 60
STA. 0+124.705 ⁸ TO STA. 0+853.440



⁸ STA. 0+182.880 TO STA. 0+243.840 - SEE ALSO PARKING AREA DETAIL

ϴ 1.2 FROM STA. 0+213.360 TO STA. 0+792.480 FOR WIDENING TO OFFSET GUARD RAIL 0.6 FROM EDGE OF SHOULDER.

DETOUR TYPICAL SECTION
STA. 0+00 TO STA. 0+622.33

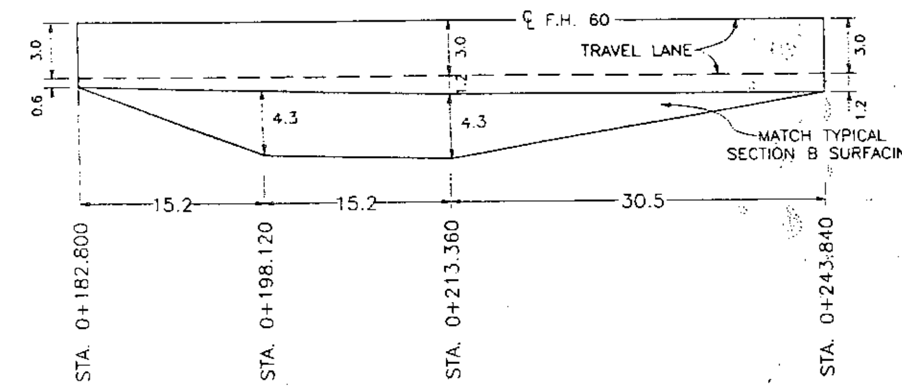


□ CONCRETE BARRIER (TEMPORARY)
SEE TABULATION OF GUARDRAIL FOR LOCATIONS

NOTE: DETOUR SURFACING PAID FOR AS SQUARE METER
(SEE SPECIAL PROVISION - SECTION 621)

▲ 1:3 EXCEPT 1:2 BEHIND GUARD RAIL

PARKING AREA DETAIL
F.H. 60 STA. 0+182.880 TO 0+243.840 RT.



MATERIAL SHALL BE PLACED IN SEPARATE COURSES AT THE FOLLOWING APPROXIMATE RATES PER 100.0 M OF ROADWAY:

	SECT. B METRIC TONS 0.6 SHOULDER	SECT. B METRIC TONS 1.2 SHOULDER
HOT BITUMINOUS PAVEMENT		
TOP LAYER	65	71
BOTTOM LAYER	68	74
AGGREGATE BASE COURSE (CL 6)	363	390
AGGREGATE BASE COURSE (CL 1)	438	464

THE RATES SHOWN HAVE BEEN DETERMINED FROM INFORMATION AVAILABLE AT TIME OF DESIGN. RATES SHOULD BE ADJUSTED DURING CONSTRUCTION TO OBTAIN THE REQUIRED APPROXIMATE THICKNESS.

ø THE CONTRACTOR WILL BE REQUIRED TO PLACE TOPSOIL TO THIS LINE AFTER COMPLETION OF PAVING OPERATION.

* APPROXIMATE THICKNESS

NOTE: THE DEPTH AND WIDTH OF THE SIDE DITCH SHALL BE VARIED WHERE NECESSARY IN ORDER TO PROVIDE PROPER DRAINAGE.

FILL SLOPES FOR TYPICAL SECTION B

SLOPE 1:4 WHERE "H" IS LESS THAN 3.0
SLOPE 1:3 WHERE "H" IS LESS THAN 4.6
SLOPE 1:2 WHERE "H" IS OVER 4.6

IN SPECIAL CASES,SLOPE MAY BE STEEPENED.

BREAK POINTS ON SLOPES AND IN BOTTOMS OF DITCHES SHALL BE ROUNDED DURING CONSTRUCTION FOR A PLEASING APPEARANCE.

10/25/93 FORES4_M.DWG 89080

AS CONSTRUCTED			FED. ROAD REGION	DIVISION	PROJ. NO.	SHEET NO.
NO REVISIONS	REVISED	VOID	VIII	COLO	BRS-PLH-CXBRS 0145(16)	5

NOTE: ALL WHOLE NUMBERS INDICATE MILLIMETERS.
ALL DECIMAL NUMBERS INDICATE METERS
UNLESS OTHERWISE INDICATED.

ROADWAY SEEDING PLAN

SOIL PREPARATION, FERTILIZING, SEEDING, AND MULCHING FOR AN ESTIMATED 3.64 HECTARES WILL BE REQUIRED WITHIN RIGHT-OF-WAY LIMITS ON ALL DISTURBED AREAS NOT SURFACED. THE FOLLOWING TYPES AND RATES SHALL BE USED:

COMMON NAME	BOTANICAL NAME	kg/ha
WESTERN WHEATGRASS	PASCOPYRUM SMITHII	6.73
MOUNTAIN BROME	BROMUS MARGINATUS	3.36
INDIAN RICEGRASS	ORYZOSIS HYMENOIDES	3.36
SLENDER WHEATGRASS	AGROPYRON TRACHYCAULUM	3.36
BLUE GRAMA GRASS V. HACHITA	BOUTELOUA GRACILIS	1.12
NEEDLEGRASS	STIPA COMATA	1.12
HARD FESCUE	FESTUCA OVINA V. DURISCULA	2.24
RED CLOVER	TRIFOLIUM PRATENSE	1.12
GLOBEMALLOW	SPHAERALCEA COCCINEA	11
YARROW	ACHILLEA MILLEFOLIUM	11
	TOTAL	22.63
COMMERCIAL FERTILIZER:	PERCENT	kg/ha
AVAILABLE NITROGEN:	18	30.26
AVAILABLE PHOSPHORUS:	46	77.34

SEEDING APPLICATION:
DRILLED TO A DEPTH OF 7 mm TO 13 mm INTO SOIL WHERE POSSIBLE. BROADCAST AND RAKE TO COVER ON STEEPER THAN 1:2 SLOPES WHERE ACCESS IS LIMITED OR UNSAFE FOR EQUIPMENT.

MULCHING REQUIREMENT AND APPLICATION:

ON SLOPES FLATTER THAN 1:2 – 4 483 kg/hectare CLEAN STRAW OR GRASS HAY MECHANICALLY CRIMPED IN COMBINATION WITH AN ORGANIC MULCH TACKIFIER (SPECIAL PROVISION 213).
ON SLOPES 1:2 OR 1:1.5 – SOIL RETENTION BLANKET (SPECIAL).
ON SLOPES OF 1:1.5 OR STEEPER (ROCKCUTS EXCULDED) – HYDRAULIC MULCH AT THE RATE OF 3 363 kg/hectare

PROJECT TOTAL

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	REMARKS
212	SEEDING (NATIVE)	HA	3.64	INCLUDES 0.69 HECTARES WETLAND MULCH
213	MULCHING	HA	2.79	
213	MULCHING (HYDRAULIC)	HA	1.62	
213	MULCH TACKIFIER	KG	313	
216	SOIL RETENTION BLANKET (SPECIAL)	M^2	1,330	

GENERAL NOTES

FOR PRELIMINARY PLAN QUANTITIES OF PAVEMENT MATERIALS, THE FOLLOWING RATES OF APPLICATION WERE USED:

PRIME COAT (MC-70) . . . . @ 1.36 L/m^2
TACK COAT DILUTED EMUL ASPHALT (SLOW-SETTING). . . @ 0.226 L/m^2
BITUMINOUS PAVEMENT. . . . . @ 59.674 $kg/m^2/25.44mm$
AGGREGATE BASE COURSE. . . . . @ 2 130.45 kg/m^3

DILUTED EMULSIFIED ASPHALT FOR TACK COAT SHALL CONSIST OF 1 PART EMULSIFIED ASPHALT AND 1 PART WATER. IT IS ESTIMATED THAT 3 937 liters OF EMULSIFIED ASPHALT (SLOW SETTING) WILL BE REQUIRED. IT IS ESTIMATED THAT 28 110 liters OF LIQUID ASPHALTIC MATERIAL (MC-70) WILL BE REQUIRED FOR PRIME COAT.

RATES OF APPLICATION SHALL BE AS DETERMINED BY THE ENGINEER AT THE TIME OF CONSTRUCTION.

ANY LAYER OF BITUMINOUS PAVEMENT THAT IS TO HAVE A SUCCEEDING LAYER PLACED THEREON SHALL BE COMPLETED FULL WIDTH BEFORE A SUCCEEDING LAYER IS PLACED.

THE FOLLOWING SHALL BE FURNISHED WITH EACH BITUMINOUS PAVER:
1. A SKI TYPE DEVICE AT LEAST 9.0 meters IN LENGTH
2. SHORT SKI OR SHOE.

VEHICLE APPROACHES THAT REQUIRE RECONSTRUCTION SHALL BE GRAVEL SURFACED, PRIMED, AND HAVE HOT BITUMINOUS PAVEMENT PLACED AS FOLLOWS:

FIELD APPROACHES – 100 mm ABC FOR THE FULL LIMITS OF APPROACH CONSTRUCTION, AND 76 mm HBP (GR. C) PAVED 3.0 meters OUT FROM THE EDGE OF SHOULDER OR TO THE RIGHT OF WAY LINE, WHICHEVER IS LESS.

ROAD APPROACHES – 100 mm (CL. 6) FOR THE FULL LIMITS OF APPROACH CONSTRUCTION AND 100 mm HBP (GR. C) PAVED 6 meters OUT FROM THE EDGE OF SHOULDER OR TO THE RIGHT OF WAY LINE WHICHEVER IS LESS.

DEPTH OF MOISTURE-DENSITY CONTROL FOR THIS PROJECT SHALL BE AS FOLLOWS:
FULL DEPTH OF ALL EMBANKMENT.
BASES OF CUT AND FILLS 150 mm.

EXCAVATION REQUIRED FOR COMPACTION OF BASES OF CUTS AND FILLS WILL BE CONSIDERED AS SUBSIDIARY TO THAT OPERATION AND WILL NOT BE PAID FOR SEPARATELY.

TYPE OF COMPACTION FOR THIS PROJECT SHALL BE AASHTO T-99.

THE MINIMUM "R" VALUE FOR THE EMBANKMENT MATERIAL SHALL BE 9. THE SOURCE FOR THIS MATERIAL SHALL BE THE CONTRACTOR'S SOURCE.

MUCK EXCAVATION AREAS SHALL BE COVERED WITH GEOTEXTILE (EROSION CONTROL) (CLASS A) AS DIRECTED.

THE MINIMUM THICKNESS OF TOPSOIL SHALL BE 100 mm. IT IS ESTIMATED THAT 3 678 m3 WILL BE REQUIRED BASED ON AVERAGE THICKNESS AND WILL BE OBTAINED FROM CONTRACTOR'S SOURCE.

220 meters OF RUMBLE STRIP ARE REQUIRED ON FH 60 AT THE APPROACH TO THE INTERSECTION WITH SH 145 AS SHOWN FOR STOP SIGN APPROACH ON STD. M-614-1.

IT IS ESTIMATED THAT 10 DELINEATORS WILL BE REMOVED.

THE EXISTING BRIDGE RAIL PAINT HAS BEEN FOUND TO CONTAIN LEAD AND SHALL BE REMOVED IN ACCORDANCE WITH SECTION 251 OF THE PROJECT SPECIAL PROVISIONS. PAINT REMOVAL WILL BE PAID FOR UNDER ITEM 251-PAINT REMOVAL AND WASTE DISPOSAL MANAGEMENT AND F/A PAINT REMOVAL AND WASTE DISPOSAL MANAGEMENT.

SUMMARY OF APPROXIMATE QUANTITIES

AS CONSTRUCTED		
NO REVISIONS	REVISED	VOID

FED. ROAD REGION	DIVISION	PROJ. NO.	SHEET NO.
VIII	COLO.	BRS-PLH-CXBRS 0145(16)	6

INDEX BOOK	INDEX PAGE	INDEX SHEET	CONTRACT ITEM NO.	CONTRACT ITEM	UNIT	ROADWAY PLAN	ROADWAY AS CONST.	MAJOR STRUCTURE N-03-F PLAN	MAJOR STRUCTURE N-03-F AS CONST.	PROJECT TOTALS PLAN	PROJECT TOTALS AS CONST.
			201	CLEARING AND GRUBBING	L S	1				1	
			202	REMOVAL OF PIPE	EACH	8				8	
			202	REMOVAL OF DELINEATOR	EACH	10				10	
			202	REMOVAL OF ASPHALT MAT	M2	2 006				2 066	
			202	REMOVAL OF PAVEMENT MARKING	M2	12				12	
			202	REMOVAL OF BRIDGE	EACH			1		1	
			202	REMOVAL OF GROUND SIGN	EACH	12				12	
			202	REMOVAL OF FENCE	M	881				881	
			202	PLUG CULVERT	EACH	1				1	
			203	EMBANKMENT MATERIAL (COMPLETE IN PLACE)	M3	57 741				57 741	
			203	MUCK EXCAVATION	M3	1 147				1 147	
			203	DOZING (LANDSCAPING)	HOUR	120				120	
			206	STRUCTURE EXCAVATION	M3	4 130		222		4 352	
			206	STRUCTURE BACKFILL (CLASS 1)	M3	283		167		450	
			207	TOPSOIL	M3	3 678				3 678	
			207	WETLAND TOPSOIL	M3	2 069				2 069	
			207	STOCKPILE WETLAND TOPSOIL	M3	2 069				2 069	
			212	SEEDING (NATIVE)	HA	3.64				3.64	
			212	SEEDING (WETLANDS)	HA	0.89				0.89	
			213	MULCHING	HA	2.79				2.79	
			213	MULCHING (HYDRAULIC)	HA	1.62				1.62	
			213	MULCH TACKIFIER	KG	313				313	
			214	DECIDUOUS TREE (50 MM CALIPER)	EACH	30				30	
			214	DECIDUOUS TREE (2.4 METER)	EACH	70				70	
			214	DECIDUOUS SHRUB (NO. 5 CONTAINER)	EACH	200				200	
			214	BRUSH LAYER CUTTING	EACH	3 728				3 720	
			214	WATTLE	EACH	156				156	
			216	SOIL RETENTION BLANKET (SPECIAL)	M2	1 330				1 330	
			251	PAINT REMOVAL AND WASTE DISPOSAL MANAGEMENT	LS	1		1		1	
			304	AGGREGATE BASE COURSE (CLASS 1)	T	3 838				3 838	
			304	AGGREGATE BASE COURSE (CLASS 6)	T	9 182				9 182	
			403	HOT BITUMINOUS PAVEMENT (GRADING C) (ASPHALT AND HYDRATED LIME)	T	9 366		98		8 464	
			411	EMULSIFIED ASPHALT (SLOW-SETTING)	L	3 937				3 937	
			411	LIQUID ASPHALTIC MATERIAL (MC-70)	L	28 110				28 110	

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SUMMARY OF APPROXIMATE QUANTITIES

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INDEX			CONTRACT ITEM NO.	CONTRACT ITEM	UNIT	ROADWAY										MAJOR STRUCTURE N-03-F								PROJECT TOTALS	
BOOK	PAGE	SHEET				PLAN	AS CONST.									PLAN	AS CONST.							PLAN	AS CONST.
			420	GEOTEXTILE (EROSION CONTROL) (CLASS A)	M2	1 788																		1 788	
			420	GEOTEXTILE (EROSION CONTROL) (CLASS B)	M2	1 376																		1 376	
			420	SILT FENCE	M	1 664																		1 664	
			420	MAINTAIN SILT FENCE	M	1 664																		1 664	
			503	DRILLED CAISSON (900 MM)	M											88								88	
			503	DRILLED CAISSON (1050 MM)	M											30								30	
			506	RIPRAP (SPECIAL)	EACH	20																		20	
			506	RIPRAP (150 MM)	m3	94																		94	
			506	RIPRAP (225 MM)	M3	1 634																		1 634	
			506	RIPRAP (450 MM)	M3	1 707																		1 707	
			507	BITUMINOUS SLOPE AND DITCH PAVING (ASPHALT)	T	17.236																		17.236	
			515	WATERPROOFING (MEMBRANE)	M2											817								817	
			601	CONCRETE CLASS A (WALL)	M3	12																		12	
			601	CONCRETE CLASS D (BRIDGE)	M3											406								406	
			602	REINFORCING STEEL	KG	260										33 548								33 808	
			602	REINFORCING STEEL (EPOXY COATED)	KG											16 566								16 566	
			604	INLET TYPE C (1 m)	EACH	2																		2	
			606	GUARDRAIL TYPE 3 (1875 MM POST SPACING)	M	945																		945	
			606	END ANCHORAGE TYPE 3E	EACH	8																		8	
			606	END ANCHORAGE TYPE 3G	EACH	4																		4	
			606	BRIDGE RAIL TYPE 10	M											103								103	
			607	END POST	EACH	13																		13	
			607	CORNER AND LINE BRACE POST	EACH	5																		5	
			607	FENCE BARBED WIRE WITH TREATED WOODEN POSTS	M	1 103																		1 103	
			607	FENCE (TEMPORARY)	M	335																		335	
			609	CURB TYPE 6 (SECTION M)	M	381																		381	
			612	DELINEATOR (TYPE I)	EACH	22																		22	
			612	DELINEATOR (TYPE II)	EACH	21																		21	
			612	DELINEATOR (TYPE III)	EACH	2																		2	
			613	CONDUIT (INSTALL ONLY)	M	274																		274	
			614	SIGN PANEL (CLASS I)	M2	7																		7	
			614	SIGN PANEL (CLASS II)	M2	6																		6	
			614	TIMBER SIGN POST 100x150 MM	M	52																		52	
			614	TIMBER SIGN POST 150x150 MM	M	29																		29	

SUMMARY OF APPROXIMATE QUANTITIES

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INDEX			CONTRACT ITEM NO.	CONTRACT ITEM	UNIT	ROADWAY										MAJOR STRUCTURE N-03-F								PROJECT TOTALS	
BOOK	PAGE	SHEET				PLAN	AS CONST.									PLAN	AS CONST							PLAN	AS CONST.
			614	RUMBLE STRIP	MM	220																		220	
			617	600 MM CULVERT PIPE	MM	109																		109	
			617	750 MM CULVERT PIPE	MM	191																		191	
			618	PRESTRESSED CONCRETE I (G1370)	M											228								228	
			620	FIELD OFFICE (CLASS 2)	EACH	1																		1	
			620	FIELD LABORATORY (CLASS 2)	EACH	1																		1	
			620	SANITARY FACILITY	EACH	1																		1	
			621	DETOUR BRIDGE	EACH	2																		2	
			621	DETOUR PAVEMENT	M2	5 472																		5 472	
			625	CONSTRUCTION SURVEYING	L S	1																		1	
			626	MOBILIZATION	L S	00.5										00.5								1	
			627	PAVEMENT MARKING PAINT	L	299																		299	
			627	100 MM PAVEMENT MARKING TAPE (REMOVABLE)	M	31																		31	
			629	SURVEY MONUMENT (TYPE1)	EACH	28																		28	
			630	FLAGGING	HOUR	5 000																		5 000	
			630	PILOT CAR OPERATION	HOUR	600																		600	
			630	TRAFFIC CONTROL SUPERVISOR	DAY	210																		210	
			630	BARRICADE (TYPE 3 M-B) (TEMPORARY)	EACH	4																		4	
			630	CONSTRUCTION TRAFFIC SIGN (PANEL SIZE A)	EACH	15																		15	
			630	CONSTRUCTION TRAFFIC SIGN (PANEL SIZE B)	EACH	25																		25	
			630	DRUM CHANNELIZING DEVICE	EACH	20																		20	
			630	DRUM CHANNELIZING DEVICE (WITH LIGHT) (FLASHING)	EACH	10																		10	
			630	DRUM CHANNELIZING DEVICE (WITH LIGHT) (STEADYBURN)	EACH	20																		20	
			630	CONCRETE BARRIER (TEMPORARY)	M	259																		259	
			630	TRAFFIC CONE	EACH	60																		60	
				FORCE ACCOUNT																					
			700	F/A MINOR CONTRACT REVISIONS	F A	00.5										00 5								1	
			700	F/A ON-THE-JOB TRAINEE	EACH	2																		2	
			700	F/A [illegible]	F A	1																		1	
			700	F/A PAINT REMOVAL [illegible]	F A											1								1	
			700	F/A ROCKFALL SAFETY	F A	1																		1	
				RIGHT OF WAY																					
			800	RIGHT OF WAY	L S	1																		1	

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STRUCTURE QUANTITIES

INDEX BOOK	INDEX PAGE	INDEX SHEET	LOCATION	REMOVAL OF PIPE EACH	UNCLASSIFIED EXCAVATION (CUBIC METER) EXCAV	DITCH	EMB	STRUCTURE EXCAVATION CUBIC METER	STRUCTURE BACKFILL CUBIC METER CL 1	INLET TYPE C (1.5 m) EACH	H	AGGREGATE BASE COURSE (CLASS 6) M TON	HOT BITUMINOUS PAVEMENT (GRADE C) M TON	CONCRETE (WALL) CUBIC METER CL.A	REINFORCING STEEL kg	RIPRAP CUBIC METERS 150	230	460	RIPRAP EACH SPEC	GEOTEXTILE (EROSION CONTROL) SQ. METERS CL.A	CL.B	CULVERT PIPE METERS 610	762	"H" OVER CULV. m	DETOUR BRIDGE EACH	END SECTIONS EACH 610	760	MISCELLANEOUS
			S.H. 145																									
			2+695.60 TO 2+956.56		*		*					⦸	⦸															
			3+156.88	1			69	101	32								4.59						25.91	3.35			2	
			3+081.263 TO 3+688.08		▬		▬					Ø	Ø												2			
			3+149.493				459					39.916	3.629															
			3+255.452	1		30		44	50														54.56	3.96			2	
			3+401.568					23	36													55.47		3.66		2		
			3+408.578 TO 3+431.438				*					*	*															
			3+421.932 TO 3+462.543	MAJOR STR. NO. N – 03 – F																								
			3+466.186 TO 3+511.906				*					*	*															
			3+529.584				83					34.473	3.629															
			3+639.312																									1 EACH PLUG CULVERT
			3+752.088 TO 3+810.000		*		*					⦸	⦸															
			FH 60																									
			0+158.496			1		19	31														41.15	4.27			2	
			0+182.880 TO 0+243.840				*					⦸	⦸															
			0+198.120	1																								
			0+213.360 TO 0+792.480		*		*					⦸	⦸															
			0+304.800	1				10	18														24.38	2.74			2	
			0+382.524	1			8	14	24								4.59						22.56	1.83			2	
			0+534.924	1			5	43	25								4.59						21.95	2.44			2	
			0+649.224	1		1	33	115	34	1	1.5			7.11	170.55		26.76			61.87		24.38		2.44				ELBOW 25° ▼
			0+713.232	1			35	102	34	1	1.5			4.43	89.81		22.94			53.51		28.65		2.13				ELBOW 30° ▼
			MUCK AREAS AS DIRECTED																	1672.25								
			CHANNEL																									
			3+352.800 TO 3+535.[illegible]		▬		359	[illegible]									1570.39	1707	20		1376.26							
			3+412.760				532									94.04												
			FROM TABULATION OF EMB (PH-[illegible]) TYPE 5					22																				
			TOTAL	[illegible]	[illegible]	⌧ [illegible]	⌧ [illegible]	[illegible]	[illegible]	2	[illegible]	⊲ 74.389	⊲ 7.258	11.54	260.36	94.04	1633.85	1707	20	1787.63	1376.26	108.50	190.81	╳	2	2	12	

▼ INCLUDED IN COST OF CULVERT PIPE

● [illegible] (ONLY)

▬ INCLUDED IN SUMMARY OF [illegible]

⦸ INCLUDED IN TABULATION OF BASE COURSE AND SURFACING

* INCLUDED IN ROADWAY QUANTITIES

⊲ CARRIED TO SURFACING PLAN

Ø INCLUDED IN TABULATION OF BASE COURSE AND SURFACING AS DETOUR PAVEMENT

⌧ CARRIED TO SUMMARY OF EARTHWORK

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AS CONSTRUCTED

SUMMARY OF EARTHWORK QUANTITIES

EMBANKMENT MATERIAL (COMPLETE IN PLACE) (NET)	m^3
FOR ROADWAY (S.H. 145)	31 528
FOR ROADWAY (F.H. 60)	18 056
FOR DETOUR	5 368
FOR REPLACING MUCK EXCAVATION	1 147
EMBANKMENT FROM STRUCTURE QUANTITIES	1 642
TOTAL	57 741
MUCK EXCAVATION	m^3
LOCATIONS AS DIRECTED	1 147
TOTAL	1 147

– FOR INFORMATION ONLY –

UNCLASSIFIED EXCAVATION	m^3
FOR ROADWAY (S.H.145)	4 804
FOR ROADWAY (F.H. 60)	14 416
FOR BUILDING DETOUR	586
FOR REMOVING DETOUR	1 715
FOR BUILDING CHANNEL	8 812
EST. FOR CUT SLOPE TREATMENT	993
DITCH EXCAVATION FROM STRUCTURE QUANTITIES	32
*FOR WETLAND MITIGATION GRADING	(7 189)
TOTAL	31 358
COMPACTION (AASHTO T-99)	
TOTAL EMBANKMENT (NET)	57 741
BASES OF CUTS AND FILLS	6 378
TOTAL	64 119

EARTHWORK QUANTITIES BALANCE

UNCLASSIFIED EXCAVATION	
TOTAL UNCLASSIFIED EXCAVATION	31 358
TOTAL FROM CONTRACTOR'S SOURCE	37 931
TOTAL	69 289
EMBANKMENT NET	
TOTAL	57 741
EMBANKMENT (NET) TIMES COMPACTION FACTOR (1.2)	
TOTAL	69 289
WETTING	kl
FOR COMPACTION (ROADWAY)	12 677
FOR AGGREGATE BASE COURSE	810
FOR DUST PALLIATIVE	379
TOTAL	13 866

* NOT CONSIDERED SUITABLE FOR EMBANKMENT MATERIAL

QUANTITIES INCLUDE PARKING AREA ON F.H. 60 AND FOR GUARDRAIL WIDENING WHERE APPROPRIATE.

TABULATION OF BASE COURSE AND SURFACING △

LOCATION	QUANTITY – metric tons: AGGREGATE BASE COURSE (CLASS 1)	AGGREGATE BASE COURSE (CLASS 6)	HOT BITUMINOUS PAVEMENT (GRADING C) (ASPHALT & HYDRATED LIME): TOP LAYER	MIDDLE LAYER	BOTTOM LAYER	DETOUR PAVEMENT m^2
S.H. 145						
95+060.95 TO 95+079.40		317	82	125	129	
95+079.40 TO 95+161.80		100	27	42	43	
95+161.80 TO 95+265.43		489	144	220	225	
95+265.43 TO 95+347.73		695	225	343	348	
95+347.73 TO 95+526.33		562	184	281	286	
95+526.33 TO 95+588.26		1 266	429	651	657	
95+588.26 TO 95+670.56		159	56	84	85	
95+670.56 TO 95+856.49		396	176	269	273	
95+856.49 TO 95+914.40		1 074	308	473	483	
95+914.40 TO 95+932.85		290	72	111	114	
FOREST ROAD (F.H.60)						
4+024.42 TO 4+097.79	137	109	19		20	
4+097.79 TO 4+121.21	321	267	48		51	
PARKING AREA:						
0+182.88 TO 0+243.84	75	71	15		15	
7+579.12 TO 7+640.08	2 689	2 258	414		431	
7+640.08 TO 7+649.80	267	221	40		42	
DETOUR						
0+339.55 TO 0+361.49						3,313
0+361.49 TO 0+373.38						116
0+413.00 TO 0+622.33						2,043
FROM STRUCTURE QUANTITIES		74	7			
IRREGULARITIES	349	835			320	
SUB-TOTALS			2 246	2 599	3 522	5 472
TOTALS	3 838	9 183		8 367		

△ CONTRACTOR'S SOURCE

QUANTITIES INCLUDE WIDENING FOR GUARDRAIL WHERE APPROPRIATE.

11/01/93 LA PLATA::(USER/89080/ACAD) EARTH_TAB.DWG 89080 1101 Qee

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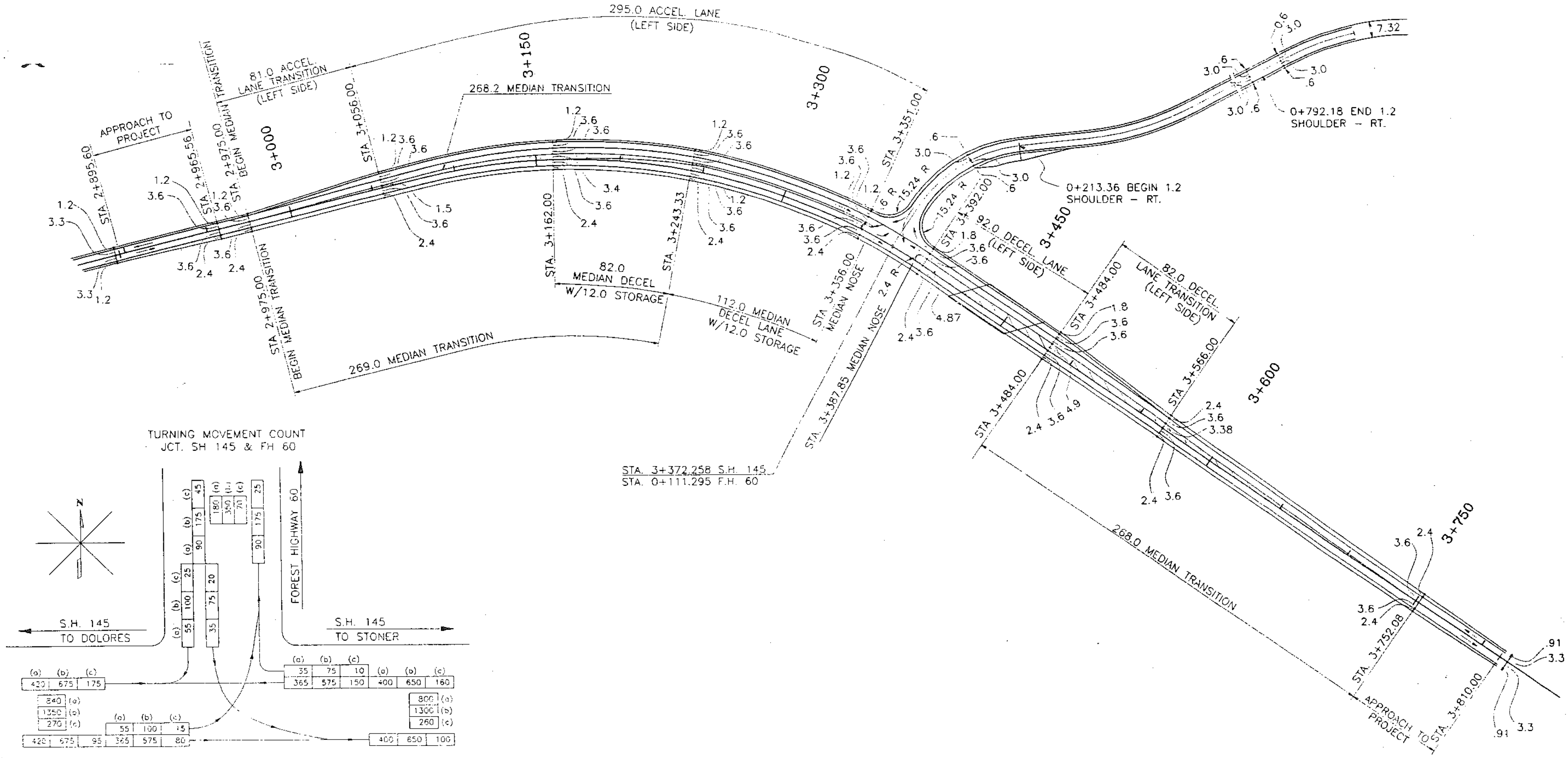
INTERSECTION DETAILS
S.H. 145 AND F.H. 60

NOTE: ALL DIMENSIONS ARE IN METERS.



TRAFFIC LEGEND

(a) = 1990 PRELIM ADT

(b) = 2012 ADT

(c) = 2012 DHV

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WETLAND MITIGATION PLAN

NOTE: WHOLE NUMBERS INDICATE MILLIMETERS.
DECIMAL NUMBERS INDICATE METERS.

MITIGATION GRADING TABULATION:

AREA	ELEVATION	UNCL EXCAV.	m^3	DEPTH OF WETLAND TOPSOIL	m^3
A	2 244.547	1.524	4 239	305	833
B	VARIES	0.457	1 671	203	735
C	VARIES	0.457	262	203	115
D	2 243.633	0.457	1 017	203	414

NOTES:

EXCAVATION OF AREAS B AND C WILL REMOVE MOST OF THE RIVER COBBLE AND BOULDERS PRIOR TO WETLAND TOPSOIL PLACEMENT.

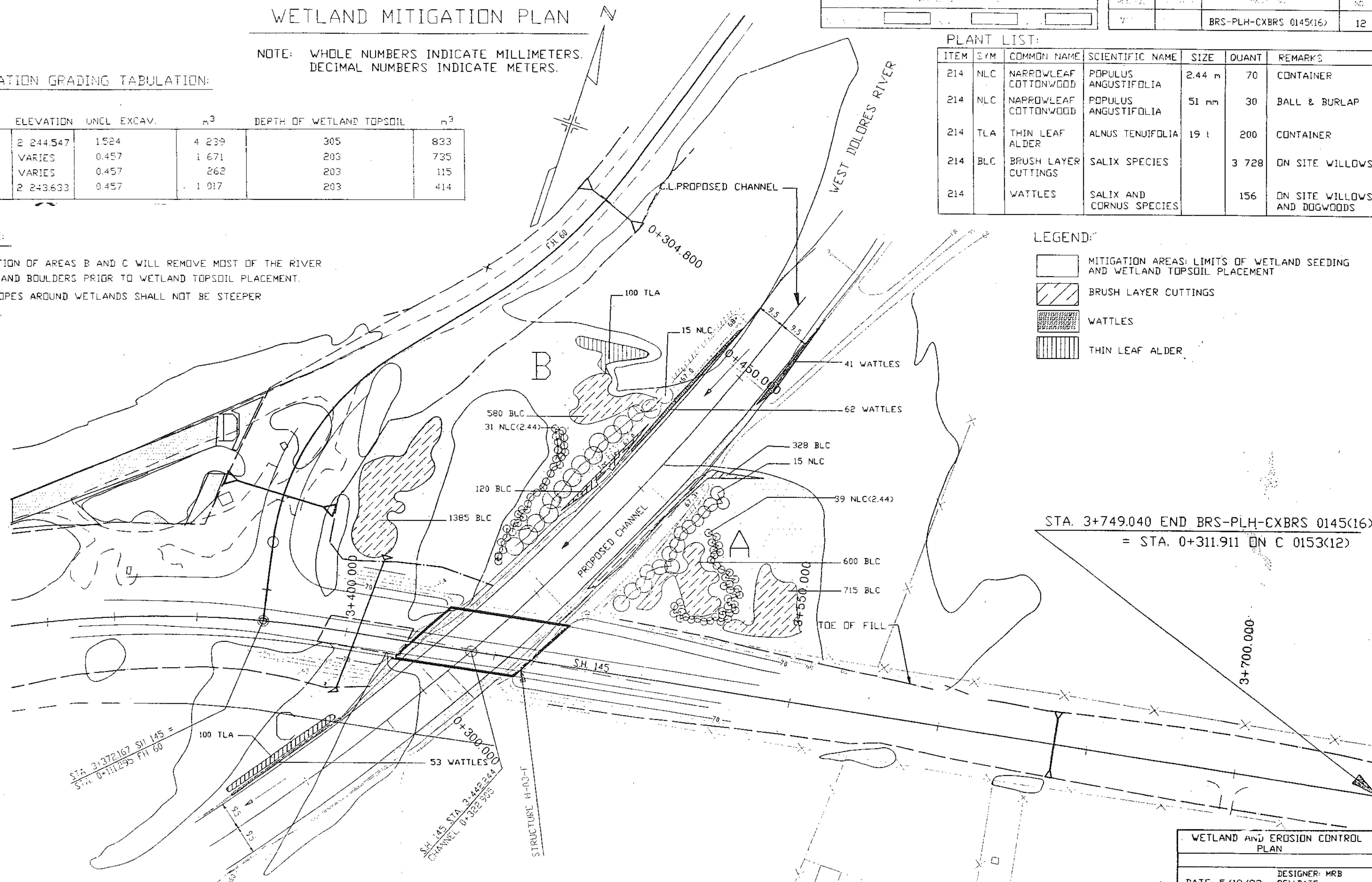
SIDE SLOPES AROUND WETLANDS SHALL NOT BE STEEPER THAN 1:3.

PLANT LIST:

ITEM	SYM	COMMON NAME	SCIENTIFIC NAME	SIZE	QUANT	REMARKS
214	NLC	NARROWLEAF COTTONWOOD	POPULUS ANGUSTIFOLIA	2.44 m	70	CONTAINER
214	NLC	NARROWLEAF COTTONWOOD	POPULUS ANGUSTIFOLIA	51 mm	30	BALL & BURLAP
214	TLA	THIN LEAF ALDER	ALNUS TENUIFOLIA	19 l	200	CONTAINER
214	BLC	BRUSH LAYER CUTTINGS	SALIX SPECIES		3 728	ON SITE WILLOWS
214		WATTLES	SALIX AND CORNUS SPECIES		156	ON SITE WILLOWS AND DOGWOODS

LEGEND:

- MITIGATION AREAS: LIMITS OF WETLAND SEEDING AND WETLAND TOPSOIL PLACEMENT
- BRUSH LAYER CUTTINGS
- WATTLES
- THIN LEAF ALDER



WETLAND AND EROSION CONTROL PLAN

DESIGNER: MRB
DATE: 5/19/92 REV.DATE:

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NOTE: WHOLE NUMBERS REPRESENT MILLIMETERS.
DECIMAL NUMBERS REPRESENT METERS.

NOTES:

DEWATERING SHALL TAKE PLACE ON A VEGETATED ADJACENT UPLAND SITE. NO WATER PUMPED FROM DEWATERING SITES SHALL BE ALLOWED TO ENTER WETLANDS OR RIVER.

DEMOLITION RUBBLE, INCLUDING ASPHALT AND CONCRETE SHALL BE DISPOSED OF AT AN APPROVED DISPOSAL SITE.

NO STAGING SHALL BE ALLOWED IN WETLAND OR RIPARIAN AREAS. THE CONTRACTOR SHALL PROVIDE THE PROJECT ENGINEER WITH A WORK PLAN FOR THE WETLAND MITIGATION AND RIPARIAN SITES SHOWING NECESSARY WORK AREAS AND HAUL ROADS

TEMPORARY FENCE WILL BE REQUIRED TO PREVENT UNNECESSARY ENCROACHMENT INTO WETLANDS AND RIPARIAN HABITAT AS SHOWN ON THE PLANS

SILT FENCE SHALL BE REQUIRED FOR EROSION CONTROL OF DISTURBED AREAS IN ACCORDANCE WITH SPECIAL PROVISION 420.

EXTEND SILT FENCE ALONG TOE OF FILL SLOPE (RIGHT) OF F.H. 60 TO LIMIT OF PROJECT.

IT IS ESTIMATED THAT 120 HRS. OF DOZING (LANDSCAPING) WILL BE REQUIRED FOR TEMPORARY EROSION CONTROL AND FINAL CONTOURING WITHIN WETLAND MITIGATION AREAS AS DIRECTED BY THE ENGINEER. A LOW GROUND PRESSURE TYPE DOZER (60–93kN) WILL BE REQUIRED FOR GRADING WITHIN WETLANDS (APPROX. 40 HRS. OF TOTAL) NO CLEAR CUTTING OF TREES AND SHRUBS SHALL BE ALLOWED TO FACILITATE EQUIPMENT ACCESS WHEN BUILDING R.O.W. FENCE.

PLANTING NOTES:

NO BARE ROOT MATERIAL WILL BE ACCEPTED.

THE CONTRACTOR SHALL PROVIDE THE ENGINEER A MINIMUM OF TWO WEEKS NOTICE OF INTENTION TO START WETLAND MITIGATION WORK TO ALLOW TIME TO COORDINATE WITH THE STAFF LANDSCAPE ARCHITECT.

FRESH WOOD CHIP MULCH (101 THICK) SHALL BE REQUIRED FOR PLANTING BASINS. WOOD CHIP WILL NOT BE PAID FOR SEPARATELY, BUT SHALL BE INCLUDED IN THE COST OF THE WORK.

SOIL CONDITIONER COMPOSTED ASPEN HUMUS OR APPROVED EQUAL SHALL BE ADDED TO BACKFILL FOR TREES. SOIL CONDITIONER SHALL BE INCLUDED IN THE COST OF THE WORK.

ALL TREE GUYING SHALL BE REMOVED BY THE CONTRACTOR PRIOR TO FINAL ACCEPTANCE OF PLANT MATERIAL.

NO FERTILIZER SHALL BE USED IN WETLAND AREAS.

STOCKPILE WETLAND TOPSOIL NOTES:

IT IS ESTIMATED THAT 2 096 m^3 OF STOCKPILE WETLAND TOPSOIL WIL BE EXCAVATED TO A DEPTH OF 300 WITHIN AREAS AS SHOWN ON THE PLANS AND STOCKPILED AS APPROVED BY THE ENGINEER.

PRIOR TO EXCAVATING WETLAND TOPSOIL, CONTRACTOR SHALL PRUNE TREES AND SHRUBS IN DESIGNATED AREAS TO 300 ABOVE GROUNDLINE WITHOUT GRUBBING ROOTS FROM SOIL. THIS WORK WILL NOT BE MEASURED AND PAID FOR SEPARATELY BUT SHALL BE INCLUDED IN THE WORK.

SEEDING (WETLAND)

SEEDING AND MULCHING WILL BE REQUIRED FOR APPROXIMATELY 0.9 HECTERS OF WETLAND MITIGATION AREAS. THE FOLLOWING TYPES AND RATES SHALL BE USED:

COMMON NAME	BOTANICAL NAME	kg/ha
REDTOP	AGROSTIS ALBA	0.11
TIMOTHY	PHLEUM PRATENSE	1.12
RED FESCUE	FESTUCA RUBRA	1.12
	TOTAL	2.35

SEEDING APPLICATION: HAND BROADCAST AND RAKE TO A DEPTH OF 7 TO 13 INTO THE TOPSOIL

MULCHING REQUIREMENT AND APPLICATION: 4.48 metric tons PER hectare STRAW, HAND PLACED AND CRIMPED INTO SOIL.

NO FERTILIZER SHALL BE USED IN WETLAND AREAS.

SEEDING (WETLAND) SHALL BE COMPLETED IMMEDIATELY AFTER WETLAND GRADING AND PLANTING.

TABULATION OF WETLAND AND EROSION CONTROL QUANTITIES

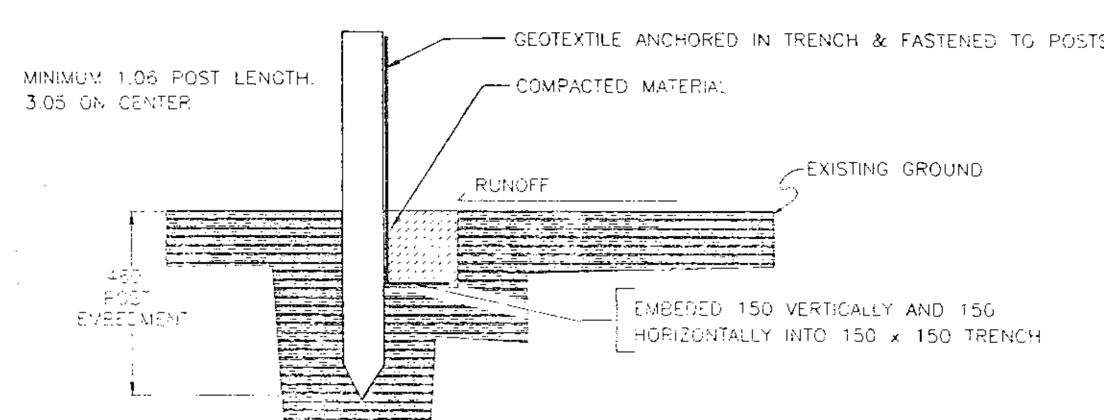
PAY ITEM	DESCRIPTION	UNIT	QUANTITY	REMARKS
203	UNCLASSIFIED EXCAVATION	M^3	7 189	CARRIED TO EWRK.TAB
203	DOZING (LANDSCAPING)	HR	120	
207	WETLAND TOPSOIL	M^3	2 096	
207	STOCKPILE WETLAND TOPSOIL	M^3	2 096	
212	SEEDING (WETLAND)	HA	2.2	
214	DECIDUOUS TREE (50 CAL.)	EACH	30	
214	DECIDUOUS TREE (2.4)	EACH	70	
214	DECIDUOUS SHRUB (19 LITER CONT)	EACH	200	
214	BRUSH LAYER CUTTING	EACH	3 728	SEE SPEC. REV. 214
214	WATTLE	EACH	156	SEE SPEC. REV. 214
420	SILT FENCE	M	1 664	SEE SPEC. REV. 420
420	MAINTAIN SILT FENCE	M	1 664	SEE SPEC. REV. 420
607	FENCE (TEMPORARY)	M	335	SEE SPEC. REV. 607

WETLAND TEST HOLE DATA AND LOCATIONS (GROUND WATER)

TEST HOLE NO.	STATION S.H. 145	OFFSET DISTANCE	ELEVATION
1	3+237.55	47.24 LT	2 243.89
2	3+363.47	60.96 LT	2 244.33
3	3+514.34	62.48 LT	2 246.04
4	3+557.02	51.82 LT	2 246.11
5	3+552.44	26.82 LT	2 246.18
6	3+493.01	26.82 LT	2 245.97

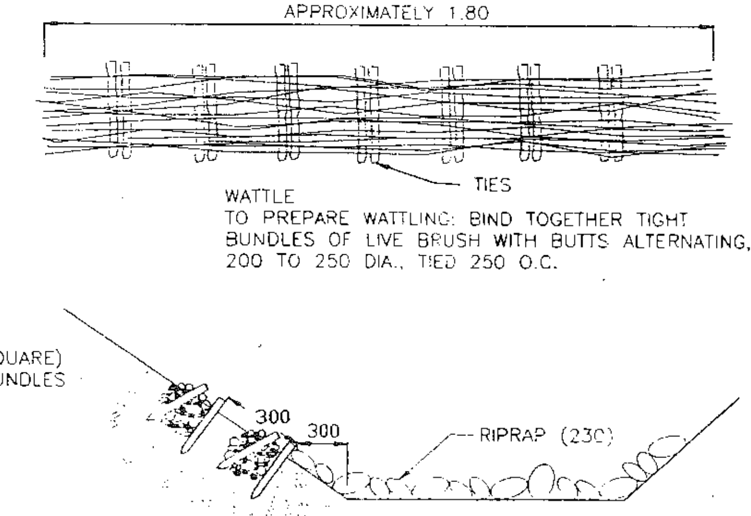
SILT FENCE (TRANSVERSE VIEW) DETAIL

NOT TO SCALE



SEE PROJECT SPECIAL PROVISIONS REVISION OF SECTION 420 – SILT FENCE FOR ADDITIONAL INFORMATION

1. STAKE ON CONTOUR
2. TRENCH ABOVE STAKES 19 DIA. OF BUNDLE.
3. PLACE BUNDLE IN TRENCH
4. ADD STAKES (30 mm SQUARE) THROUGH AND BELOW BUNDLES
5. COVER WATTLING WITH SOIL, WATER IN AND SETTLE IN SOIL.



WATTLE
TO PREPARE WATTLING: BIND TOGETHER TIGHT BUNDLES OF LIVE BRUSH WITH BUTTS ALTERNATING, 200 TO 250 DIA., TIED 250 O.C.

WATTLE DETAIL

NOT TO SCALE

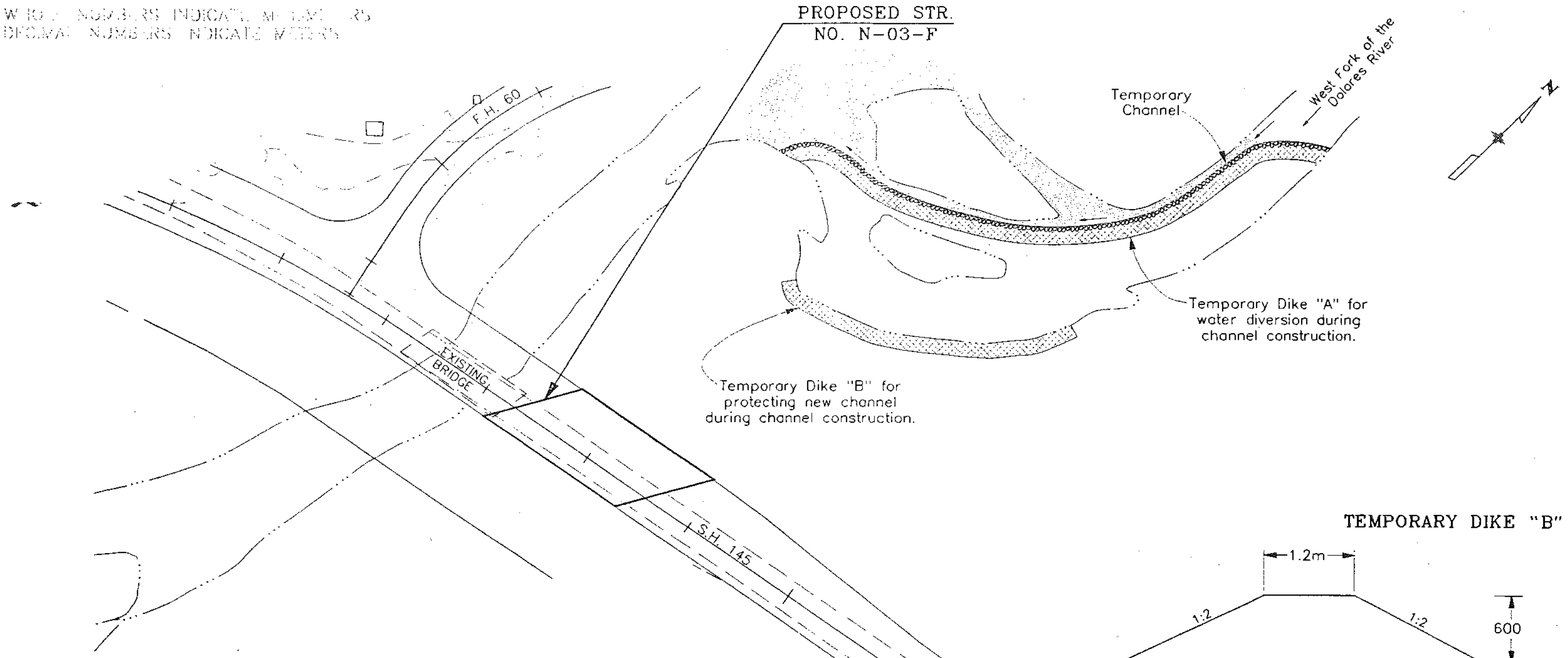
WETLAND AND EROSION CONTROL NOTES AND TABULATIONS

DESIGNER: MRB
DATE: 5/19/92
REV DATE:

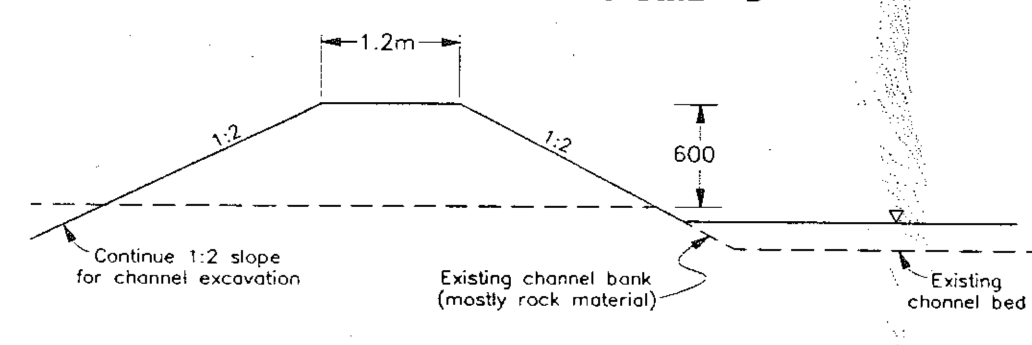
TEMPORARY WATER DIVERSION PLAN

AS CONSTRUCTED	FED. ROAD REGION	DIVISION	PROJ. NO.	SHEET NO.
NO REVISIONS / REVISED / VOID		COLO.	BRS-PLH-CXBRS 0145(16)	14

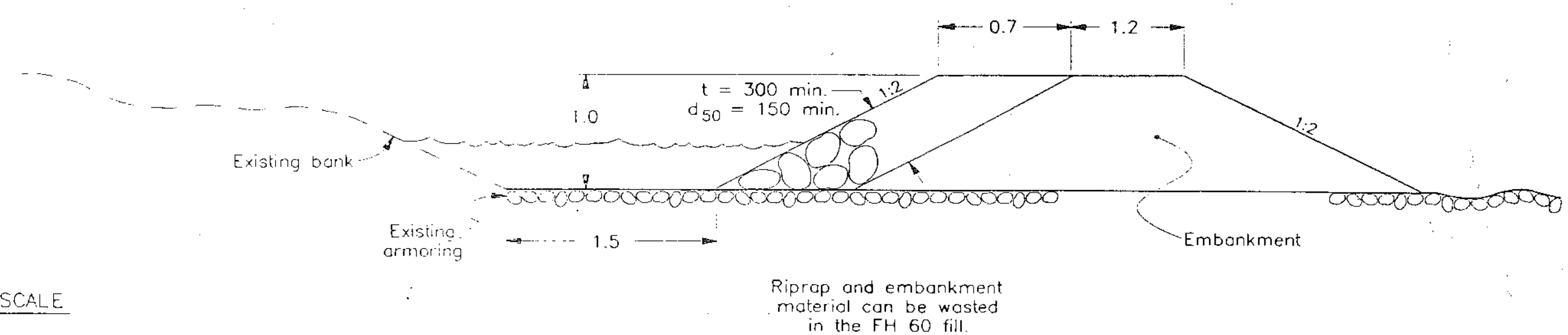
NOTE: WHOLE NUMBERS INDICATE MILLIMETERS
DECIMAL NUMBERS INDICATE METERS



TEMPORARY DIKE "B"



TEMPORARY CHANNEL AND DIKE "A"



*QUANTITIES

RIPRAP (150mm)	94	m^3
EMBANKMENT	592	m^3

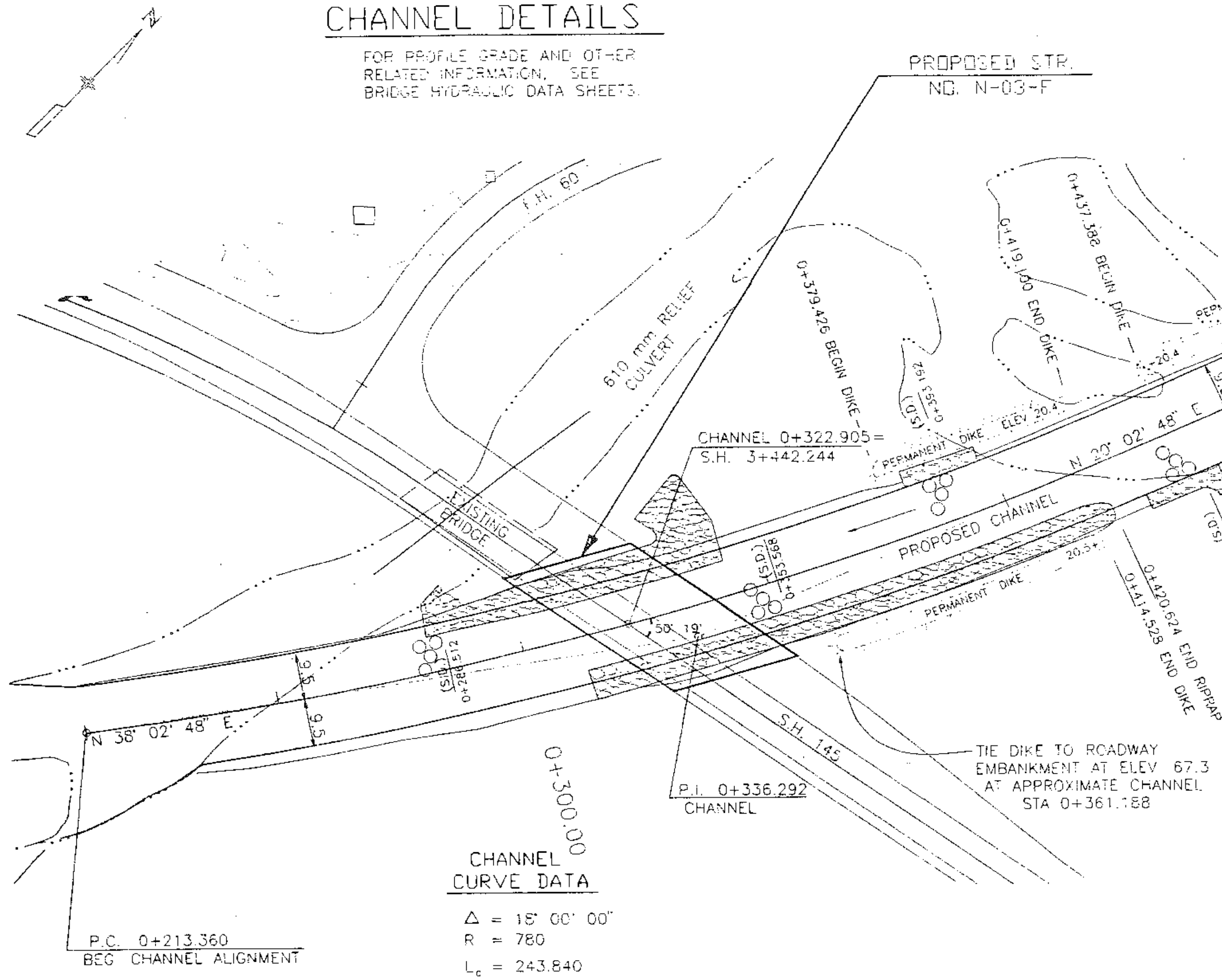
* CARRIED TO STRUCTURE QUANTITIES

NOT TO SCALE

NOTE: WHOLE NUMBERS INDICATE MILLIMETERS
DECIMAL NUMBERS INDICATE METERS

CHANNEL DETAILS

FOR PROFILE GRADE AND OTHER RELATED INFORMATION, SEE BRIDGE HYDRAULIC DATA SHEETS.



CHANNEL CURVE DATA

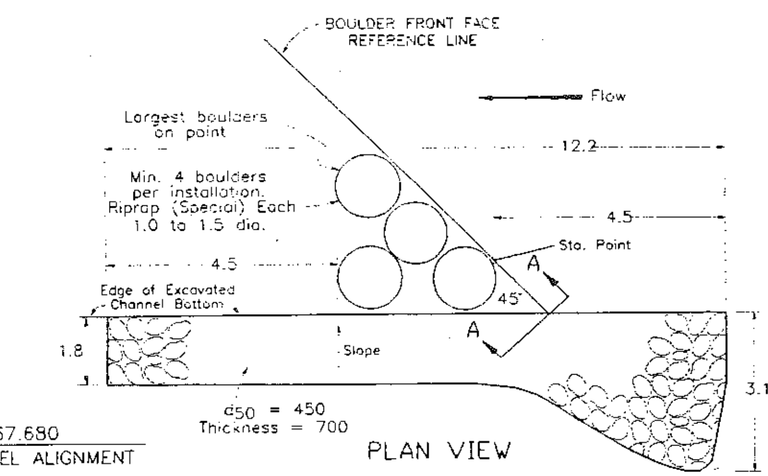
Δ = 15° 00' 00"
R = 780
L_c = 243.840
T_L = 122 933

LEGEND

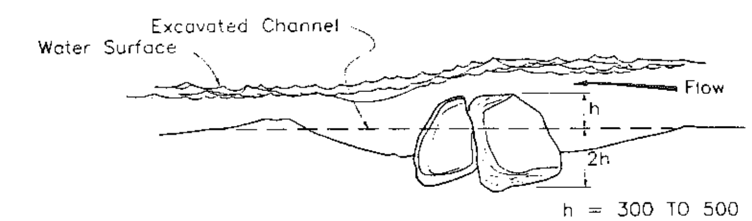
- STREAM DEFLECTOR (S.D.)
- RIPRAP
- SHORE LINE
- CUT SLOPES

STREAM DEFLECTOR

CHANNEL STA. 0+296.512, 0+353.568, 0+393.192, 0+432.816, 0+472.440

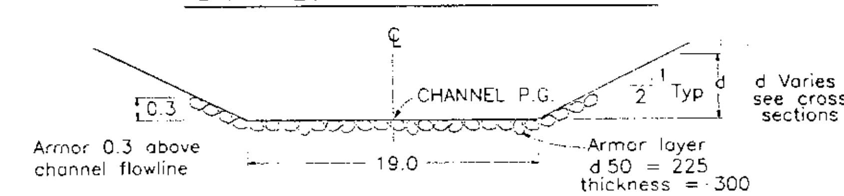


PLAN VIEW

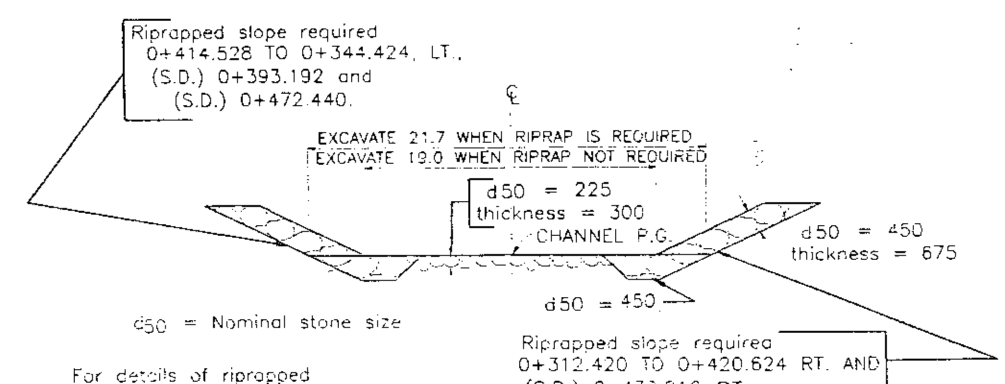


SECTION A-A

CHANNEL TYPICAL SECTIONS



CHANNEL SECTION WHERE RIPRAP IS NOT REQUIRED



d_{50} = Nominal stone size

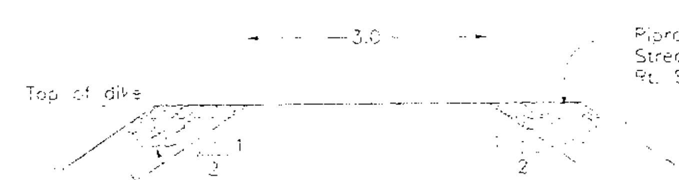
For details of riprapped slope, see Bridge Hydraulic Information Sheet.

CHANNEL TRANSITION

From riprap slope to non-riprap slope
(Maintain 18 width clear channel bottom)

PERMANENT DIKE TYPICAL

0+361.188 TO 0+414.528 RT.
0+379.476 TO 0+419.100 LT.
0+437.388 TO 0+469.392 LT.



Riprap as required at Stream Deflector locations Rt. Side of Dike only.

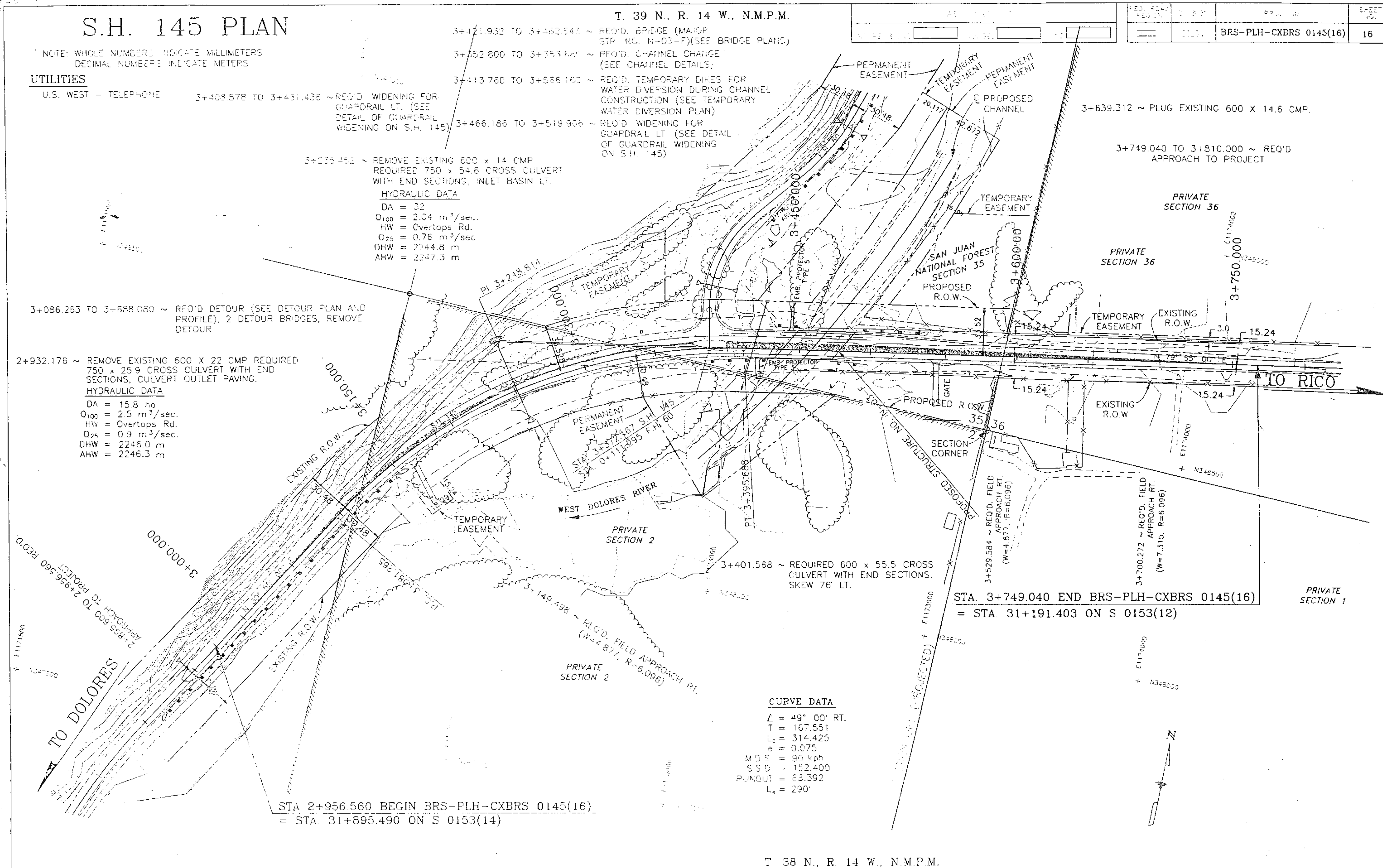
Riprap as required 0+361.188 to 0+420.624 Lt. Side of Dike only

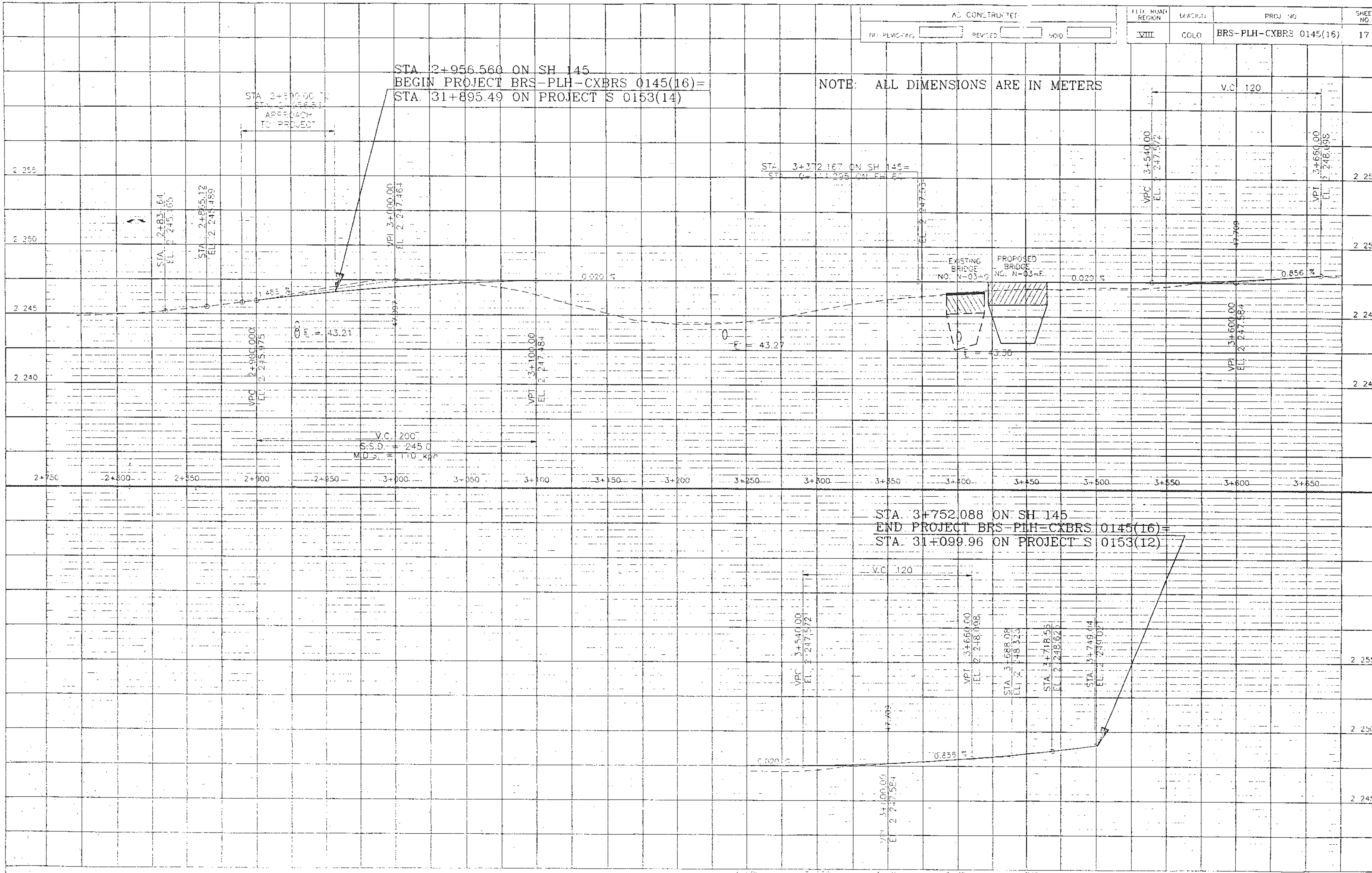
⁎ QUANTITIES

EMBANKMENT	359	m^3
STRUCTURE EXCAVATION	3 636	m^3
RIPRAP (225 mm)	1 570	m^3
RIPRAP (450 mm)	1 707	m^3
RIPRAP (SPECIAL)	20	EACH
GEOTEXTILE (ER) (B)	1 376	m^2

⁎ CARRIED TO STRUCTURE QUANTITIES.

10/25/93 SHEETB_M.DWG 89080


S.H. 145 PLAN
NOTE: WHOLE NUMBERS INDICATE MILLIMETERS
DECIMAL NUMBERS INDICATE METERS
UTILITIES
U.S. WEST - TELEPHONE
T. 39 N., R. 14 W., N.M.P.M.
BRS-PLH-CXBRS 0145(16)
16
3+421.932 TO 3+462.543 ~ REQ'D. BRIDGE (MAJOR STR. NO. N-03-F)(SEE BRIDGE PLANS)
3+252.800 TO 3+353.640 ~ REQ'D. CHANNEL CHANGE (SEE CHANNEL DETAILS)
3+413.760 TO 3+566.160 ~ REQ'D. TEMPORARY DIKES FOR WATER DIVERSION DURING CHANNEL CONSTRUCTION (SEE TEMPORARY WATER DIVERSION PLAN)
3+408.578 TO 3+431.438 ~ REQ'D. WIDENING FOR GUARDRAIL LT. (SEE DETAIL OF GUARDRAIL WIDENING ON S.H. 145)
3+466.186 TO 3+519.906 ~ REQ'D. WIDENING FOR GUARDRAIL LT. (SEE DETAIL OF GUARDRAIL WIDENING ON S.H. 145)
3+235.452 ~ REMOVE EXISTING 600 x 14 CMP REQUIRED 750 x 54.6 CROSS CULVERT WITH END SECTIONS, INLET BASIN LT.
HYDRAULIC DATA
DA = 32
Q100 = 2.04 m³/sec.
HW = Overtops Rd.
Q25 = 0.76 m³/sec
DHW = 2244.8 m
AHW = 2247.3 m
3+086.263 TO 3+688.080 ~ REQ'D DETOUR (SEE DETOUR PLAN AND PROFILE), 2 DETOUR BRIDGES, REMOVE DETOUR
2+932.176 ~ REMOVE EXISTING 600 X 22 CMP REQUIRED 750 x 25.9 CROSS CULVERT WITH END SECTIONS, CULVERT OUTLET PAVING.
HYDRAULIC DATA
DA = 15.8 ha
Q100 = 2.5 m³/sec.
HW = Overtops Rd.
Q25 = 0.9 m³/sec.
DHW = 2246.0 m
AHW = 2246.3 m
3+639.312 ~ PLUG EXISTING 600 X 14.6 CMP.
3+749.040 TO 3+810.000 ~ REQ'D APPROACH TO PROJECT
PERMANENT EASEMENT
TEMPORARY EASEMENT
PERMANENT EASEMENT
℄ PROPOSED CHANNEL
PRIVATE SECTION 36
PRIVATE SECTION 36
SAN JUAN NATIONAL FOREST SECTION 35
PROPOSED R.O.W.
TEMPORARY EASEMENT
EXISTING R.O.W.
TO RICO
PROPOSED R.O.W.
GATE
EXISTING R.O.W.
SECTION CORNER
PI 3+248.814
PERMANENT EASEMENT
STA. 3+372.467 S.H. 145
STA. 0+111.095 F.H. 60
WEST DOLORES RIVER
PRIVATE SECTION 2
PT 3+395.688
PROPOSED STRUCTURE NO. N-03-F
3+529.584 ~ REQ'D. FIELD APPROACH RT. (W=4.877, R=6.096)
3+700.272 ~ REQ'D. FIELD APPROACH RT. (W=7.315, R=6.096)
3+401.568 ~ REQUIRED 600 x 55.5 CROSS CULVERT WITH END SECTIONS. SKEW 76° LT.
STA. 3+749.040 END BRS-PLH-CXBRS 0145(16)
= STA 31+191.403 ON S 0153(12)
PRIVATE SECTION 1
EXISTING R.O.W.
TEMPORARY EASEMENT
3+149.498 ~ REQ'D. FIELD APPROACH RT. (W=4.877, R=6.096)
PRIVATE SECTION 2
2+895.600 TO 2+956.560 REQ'D. APPROACH TO PROJECT
TO DOLORES
CURVE DATA
Δ = 49° 00' RT.
T = 167.551
Lc = 314.425
e = 0.075
M.D.S. = 90 kph
S.S.D. = 152.400
RUNOUT = 83.392
Ls = 290'
STA 2+956.560 BEGIN BRS-PLH-CXBRS 0145(16)
= STA. 31+895.490 ON S 0153(14)
N
T. 38 N., R. 14 W., N.M.P.M.


AS CONSTRUCTED
NO REVISIONS
REVISED
VOID
FED. ROAD REGION
VIII
DIVISION
COLO
PROJ. NO.
BRS-PLH-CXBRS 0145(16)
SHEET NO.
17
STA. 2+956.560 ON SH 145
BEGIN PROJECT BRS-PLH-CXBRS 0145(16)=
STA. 31+895.49 ON PROJECT S 0153(14)
NOTE: ALL DIMENSIONS ARE IN METERS
APPROACH TO PROJECT
VPI 3+000.00
EL. 2 247.464
VPC 2+900.000
EL. 2 245.975
VPI 3+100.00
EL. 2 247.484
V.C. 200
S.S.D. = 245.0
M.D.S. = 110 kph
1.483 %
0.020 %
0.856 %
℄ EL. = 43.21
℄ = 43.27
EXISTING BRIDGE NO. N-03-G
PROPOSED BRIDGE NO. N-03-F
V.C. 120
VPC 3+540.00
EL. 2 247.572
VPI 3+660.00
EL. 2 248.098
VPI 3+600.00
EL. 2 247.584
STA. 3+752.088 ON SH 145
END PROJECT BRS-PLH-CXBRS 0145(16)=
STA. 31+099.96 ON PROJECT S 0153(12)
V.C. 120
VPC 3+540.00
VPI 3+660.00
0.020 %
0.855 %
2 255
2 250
2 245
2 240
2+750
2+800
2+850
2+900
2+950
3+000
3+050
3+100
3+150
3+200
3+250
3+300
3+350
3+400
3+450
3+500
3+550
3+600
3+650

AS CONSTRUCTED			FED. ROAD REGION	DIVISION	PROJ. NO.	SHEET NO.
NO REVISIONS	REVISED	VOID	VIII	COLO.	BRS-PLH-CXBRS 0145(16)	18

TABULATION OF SIGNING QUANTITIES

ITEM NO.	ITEM	UNIT	PROJECT TOTALS
202	REM PAVEMENT MARKING	M2	12.1
202	REM GROUND SIGN	EA	12
614	SIGN PANEL (CLASS I)	M2	6.9
614	SIGN PANEL (CLASS III)	M2	6.2
614	TIMBER SIGN POST (100X100)	M	53
614	TIMBER SIGN POST (150X150)	M	29
627	PVMT MKG PAINT	LT	299
627	10 CM PVMT MKG TAPE (REM)	M	31
630	CONST TRAF SIGN (A)	EA	15
630	CONST TRAF SIGN (B)	EA	25
630	BARRICADE (3M-B) (TEMP)	EA	4
630	DRUM CHANNELIZING DEVICE	EA	20
630	DRUM CHANNELIZING DEVICE (LIGHT) (F)	EA	10
630	DRUM CHANNELIZING DEVICE (LIGHT) (SB)	EA	20
630	TRAFFIC CONE	EA	60

SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES

SIGNS

SIGN CODE	LEGEND	DIMENSIONS (mm)	PANEL SIZE A	PANEL SIZE B	PANEL SIZE C
1500G20-2	END/CONSTRUCTION	1500X600		3	
1200W20-1	ROAD/CONSTRUCTION/(DIST)	1200X1200		3	
1200W20-2	DETOUR/(DIST)	1200X1200		2	
1200W20-4	ONE LANE/ROAD/(DIST)	1200X1200		3	
1200W20-7a	Flagger Symbol	1200X1200		3	
1200W8-3a	Pavement Ends Symbol	1200X1200		2	
1200W1-2(L)	Curve Arrow	1200X1200		1	
1200W1-4(R)	Reverse Curve Arrow	1200X1200		2	
450W1-8	Chevron	450X600	6		
750R1-1	STOP	750 OCT.	1		
600R2-1M(60)	SPEED/LIMIT/60	600X750	2		
600R2-1M(80)	SPEED/LIMIT/80	600X750	2		
1200R11-2	ROAD/CLOSED	1200X750		3	
1200M4-10(L)	Detour Arrow	1200X450	1		
1200M4-10(R)	Detour Arrow	1200X450	1		
1200W1-7	Double Head Arrow	1200X600	1		
1200W20-51a	Give 'em a/BRAKE	1200X1200		3	
900G20-4	PILOT CAR/FOLLOW ME	900X450	1		
		SIGN TOTALS	15	25	0

OTHER DEVICES

ITEM	QUANTITY
BARRICADE (3M-B) (TEMP)	4
DRUM CHANNELIZING DEVICE	20
DRUM CHANNELIZING DEVICE (F)	10
DRUM CHANNELIZING DEVICE (SB)	20
TRAFFIC CONE (700 mm)	60

NOTES:

BASED UPON SIGHT DISTANCE AND OTHER CONSIDERATIONS, THE FINAL LOCATION OF THESE SIGNS IS SUBJECT TO APPROVAL BY THE PROJECT ENGINEER.

SEE CASES IV & V OF STANDARD S-614-50 OF THE COLORADO STANDARD PLANS FOR BASIC PLACEMENT DETAILS OF THE CONSTRUCTION TRAFFIC CONTROL DEVICES.

G20-2 THIS SIGN SHOULD BE ERECTED APPROXIMATELY 150 METERS BEYOND THE END OF THE PROJECT.

M4-10( ) THIS SIGN SHOULD BE MOUNTED JUST BELOW THE ROAD CLOSED SIGN AT THE POINT WHERE THE DETOUR ROADWAY OR ROUTE HAS BEEN ESTABLISHED DUE TO THE CLOSURE OF THE STREET OR HIGHWAY TO THROUGH TRAFFIC.

R2-1( ) THESE SIGNS ARE INTENDED TO REDUCE TRAFFIC SPEED IN ADVANCE OF THE DAILY WORK AREA WITHIN THE OVERALL PROJECT LIMITS.

R11-2 THIS SIGN IS TO BE MOUNTED ON A TYPE (3M-B) BARRICADE AND PLACED BEFORE THE WORK ZONE ENTRANCE TO PROHIBIT TRAFFIC FROM ENTERING THE WORK ZONE.

W1-2( ) THIS SIGN IS USED WHERE ENGINEERING INVESTIGATIONS OF ROADWAY CONDITIONS SHOW THE RECOMMENDED SPEED ON THE CURVE TO BE IN THE RANGE BETWEEN 50 & 100 KILOMETERS PER HOUR.

W1-4( ) THIS SIGN IS USED WHERE TWO CURVES IN OPPOSITE DIRECTIONS ARE SEPARATED BY A TANGENT OF LESS THAN 180 METERS.

W8-3a THIS SIGN IS USED IN ADVANCE OF A POINT WHERE THE PAVEMENT SURFACE CHANGES FROM A HARD-SURFACED PAVEMENT TO THE LOW-TYPE SURFACE OR EARTH ROAD.

W20-1 THIS SIGN IS TO BE LOCATED IN ADVANCE OF THE INITIAL ACTIVITY OR DETOUR A DRIVER MAY ENCOUNTER, AND IS INTENDED TO BE USED AS A WARNING OF OBSTRUCTIONS OR RESTRICTIONS.

W20-2 THIS SIGN IS INTENDED FOR USE IN ADVANCE OF A POINT AT WHICH TRAFFIC IS DIVERTED OVER A TEMPORARY ROADWAY OR ROUTE.

W20-2 THIS SIGN IS INTENDED FOR USE ONLY IN ADVANCE OF A POINT WHERE TRAFFIC IN BOTH DIRECTIONS MUST USE A SINGLE LANE.

W20-7a THIS SIGN IS INTENDED FOR USE 150 METERS IN ADVANCE OF ANY POINT AT WHICH A FLAGGER HAS BEEN STATIONED TO CONTROL TRAFFIC THROUGH OR AROUND THE PROJECT.

W20-51a THIS SIGN SHOULD BE USED BETWEEN THE FIRST AND SECOND CONSTRUCTION WARNING SIGNS SUCH THAT IT DOES NOT INTERFERE WITH ANY OTHER SIGN.

G20-4 THIS SIGN SHALL BE MOUNTED IN A CONSPICUOUS POSITION ON THE REAR OF A VEHICLE USED FOR GUIDING ONE-WAY TRAFFIC THROUGH OR AROUND THE PROJECT.

APPROXIMATELY 201 LITERS (121 LITER YELLOW AND 80 LITER WHITE) OF PAVEMENT MARKING PAINT WILL BE REQUIRED FOR THE FINAL PAVEMENT MARKING AND 98 LITERS (49 LITER YELLOW AND 49 LITER WHITE) WILL BE REQUIRED FOR TEMPORARY PAVEMENT MARKING.

ALL TYPE 3 BARRICADES SHALL BE EQUIPPED WITH WARNING LIGHTS.

AS CONSTRUCTED	FED. ROAD REGION	DIVISION	PROJ. NO.	SHEET NO.
NO REVISIONS ☐ REVISED ☐ VOID ☐	VIII	COLO.	BRS-PLH-CXBRS 0145(18)	19

TABULATION OF SIGNS

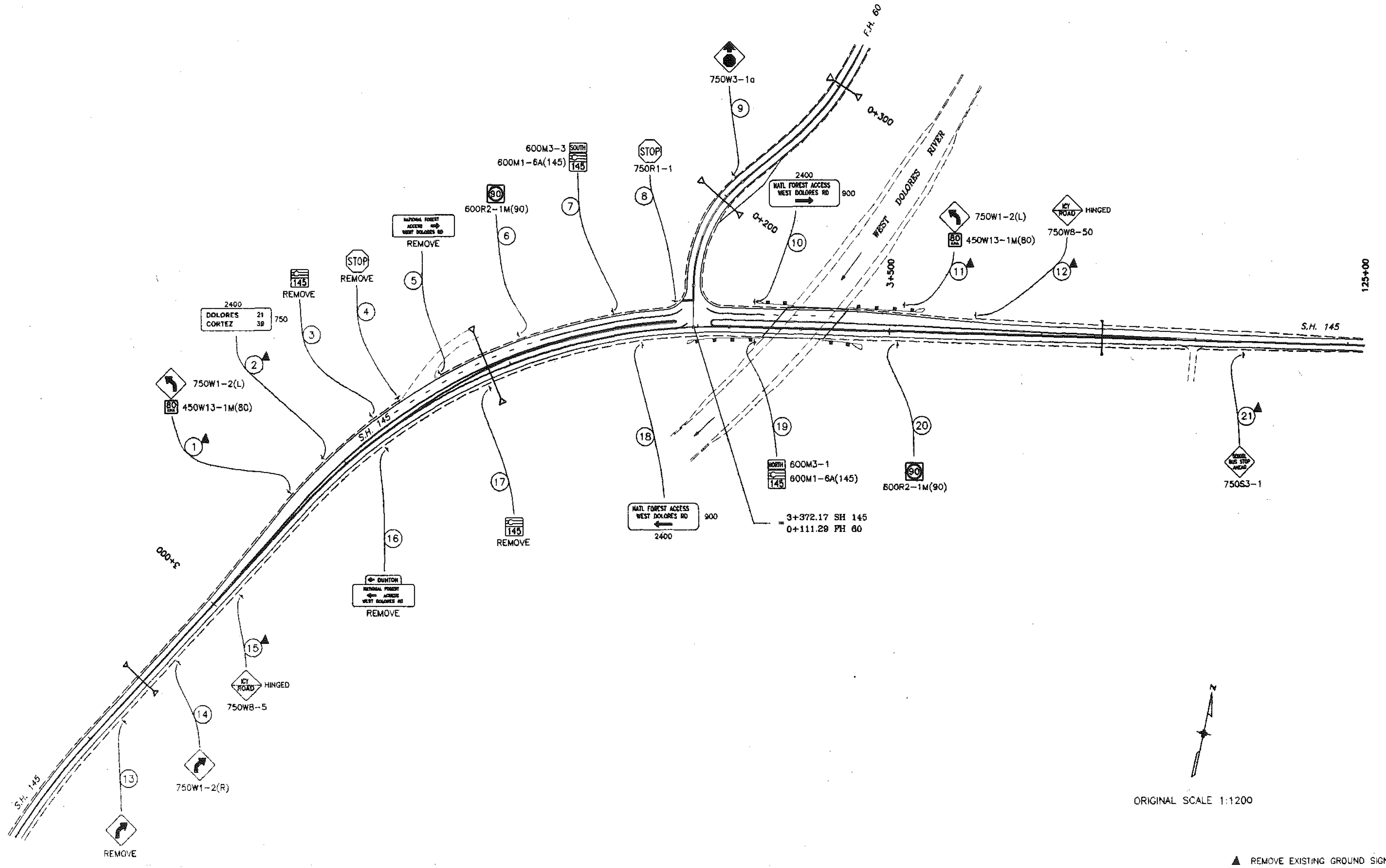
SIGN NO.	SIGN CODE	STATION	SIGN PANEL SIZE (mm)	BACK-GROUND COLOR	REMOVE GROUND SIGN (EACH)	RESET GROUND SIGN (EACH)	NO. OF POSTS	LENGTH OF POST (meters)	POST TYPE (meters) 100X100 TIMBER	150X150 TIMBER	W150X300 BEAM	W150X375 BEAM	W200X450 BEAM	W200X525 BEAM	W250X550 BEAM	W250X650 BEAM	W300X875 BEAM	W300X1000 BEAM	U-2	CONC FOOTING TYPE (EACH) 1	2	3	4	5	6	7	8	SIGN PANEL (m^2) CLASS I	CLASS II	CLASS III
1A	750W1-2(L)	3+088	750 DIAMOND	YELLOW	1		1	4.3	4.3																			0.56		
1B	450W13-1M(80)		450 X 450	YELLOW																								0.20		
2	SPECIAL	3+118	2400 X 750	GREEN	1		2	4.7		9.4																				1.80
3		3+155			1																									
4		3+176			1																									
5		3+206			1																									
6	600R2-1M(90)	3+261	600 X 750	WHITE			1	4.4	4.4																			0.45		
7A	600M3-3	3+322	600 X 300	WHITE			1	4.6	4.6																			0.18		
7B	600M1-6A(145)		600 X 600	WHITE																								0.36		
8	750R1-1	0+128 FH 60	750 OCTAGON	RED			1	4.3	4.3																			0.56		
9	750W3-1a	0+213 FH 60	750 DIAMOND	YELLOW			1	4.4	4.4																			0.56		
10	SPECIAL	3+414	2400 X 900	GREEN			2	4.9		9.8																				2.16
11A	750W1-2(L)	3+505	750 DIAMOND	YELLOW	1		1	4.3	4.3																			0.56		
11B	450W13-1M(80)		450 X 450	YELLOW																								0.20		
12	750W8-50	3+554	750 DIAMOND	YELLOW	1		1	4.4	4.4																			0.56		
13		2+9002			1																									
14	750W1-2(R)	2+957	750 DIAMOND	YELLOW			1	4.4	4.4																			0.56		
15	750W8-50	3+021	750 DIAMOND	YELLOW	1		1	4.4	4.4																			0.56		
16		3+149			1																									
17		3+231			1																									
18	SPECIAL	3+338	2400 X 900	GREEN			2	4.9		9.8																				2.16
19A	600M3-1	3+414	600 X 300	WHITE			1	4.6	4.6																			0.18		
19B	600M1-6A(145)		600 X 600	WHITE																								0.36		
20	600R2-1M(90)	3+505	600 X 750	WHITE			1	4.4	4.4																			0.45		
21	750S3-1	3+728	750 DIAMOND	YELLOW	1		1	4.4	4.4																			0.56		
	PROJECT TOTALS				12	—	—	—	52.9	29.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6.86	—	6.12

NOTES:

1. POST LENGTHS ARE APPROXIMATE ONLY. EXACT LENGTHS TO BE DETERMINED BY THE ENGINEER.

AS CONSTRUCTED	FED. ROAD REGION	DIVISION	PROJ. NO.	SHEET NO.
NO REVISIONS REVISED VOID	VIII	COLO.	BRS-PLH-CXBRS 0145(16)	20

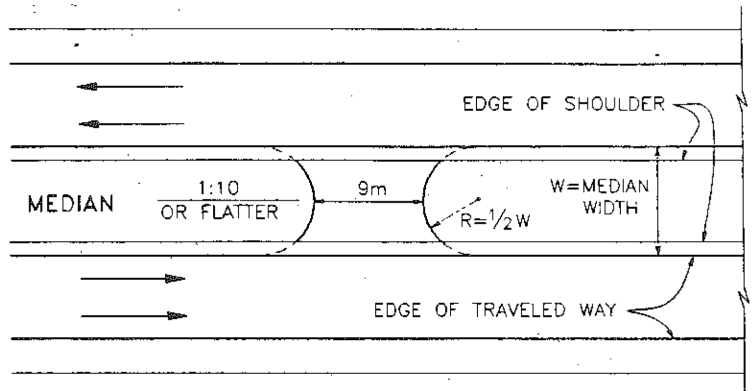
SIGNING AND STRIPING PLAN



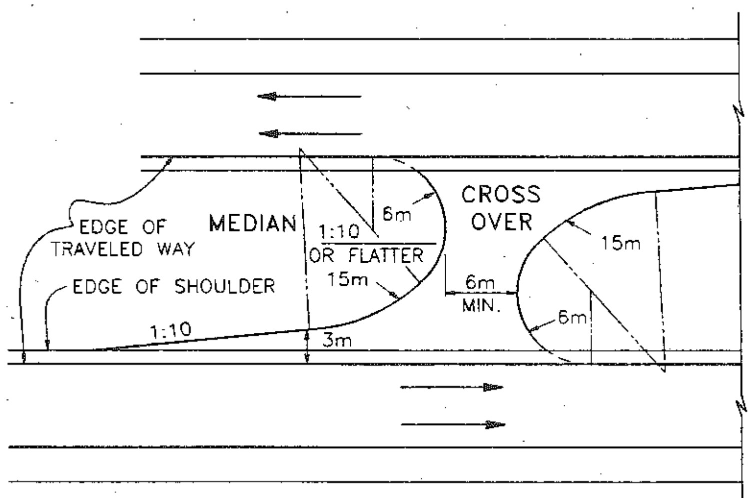
REG 1/19/94 REGION 3 C:\PLAN3.dwg

REVISIONS	M-203-1

NOTE: ALL DIMENSIONS ARE MILLIMETERS mm UNLESS OTHERWISE NOTED.

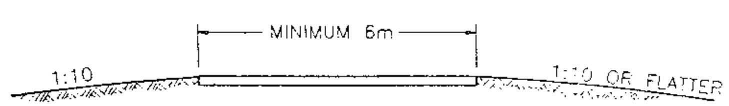


MEDIAN WIDTH LESS THAN 15m



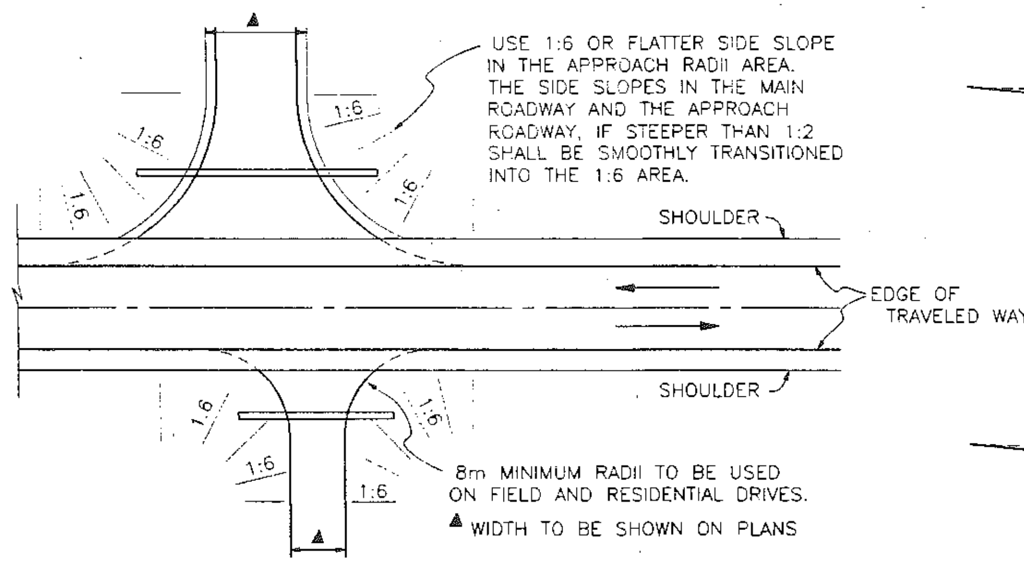
MEDIAN WIDTH GREATER THAN 15m

TYPICAL PLANS FOR EMERGENCY MEDIAN CROSS OVER



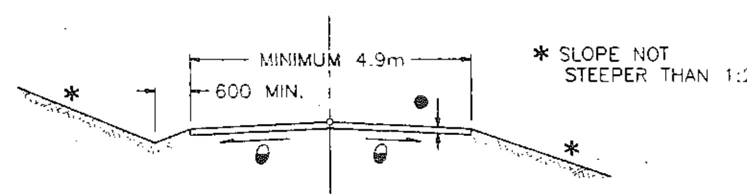
TYPICAL SECTION FOR MEDIAN CROSS OVER

ANY REQUIRED PIPE OR INLET FOR MEDIAN DRAINAGE SHALL HAVE A TRAVERSABLE DESIGN AS SPECIFIED ON THE PLANS.



SIDE DRAINS SHALL BE LOCATED BEYOND THE CLEAR ZONE, OR WHEN WITHIN THE CLEAR ZONE, SHALL BE INSTALLED WITH END SECTIONS CONFORMING TO A 1:6 SLOPE. 15m RADII TO BE USED ON INTERSECTING ROADS, EXCEPT FIELD AND RESIDENTIAL DRIVES, UNLESS OTHERWISE SPECIFIED ON PLANS. RADII MAY BE VARIED TO SUIT FIELD CONDITIONS.

TYPICAL PLANS FOR SIDE APPROACH ROAD



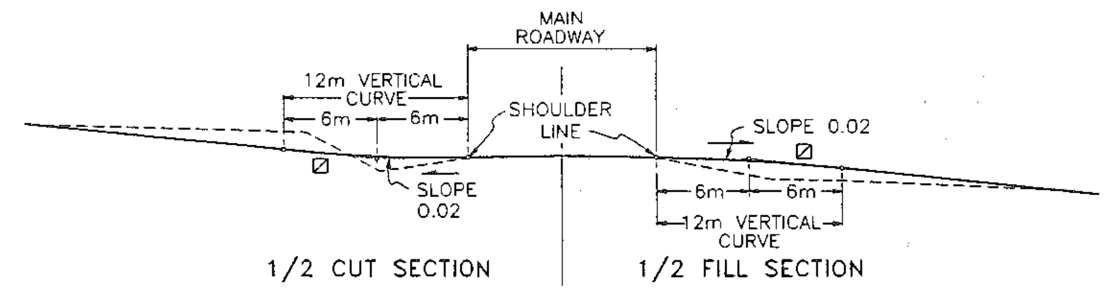
1/2 CUT SECTION 1/2 FILL SECTION

TYPICAL SECTION FOR APPROACH

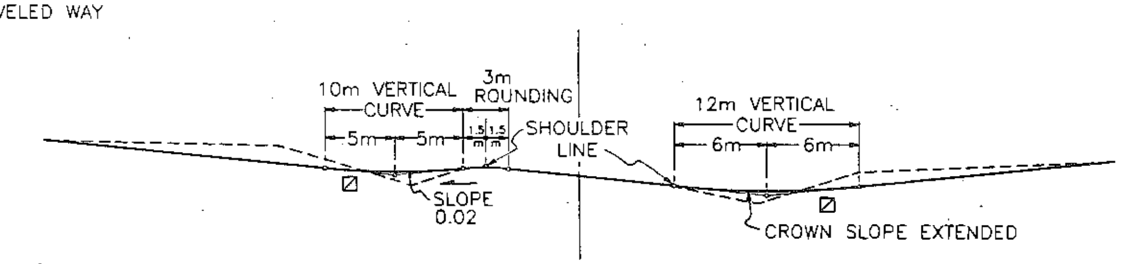
0.02 m/m

● ROAD APPROACHES WHICH REQUIRE BITUMINOUS PAVEMENT, SHALL BE PLACED AS FOLLOWS:

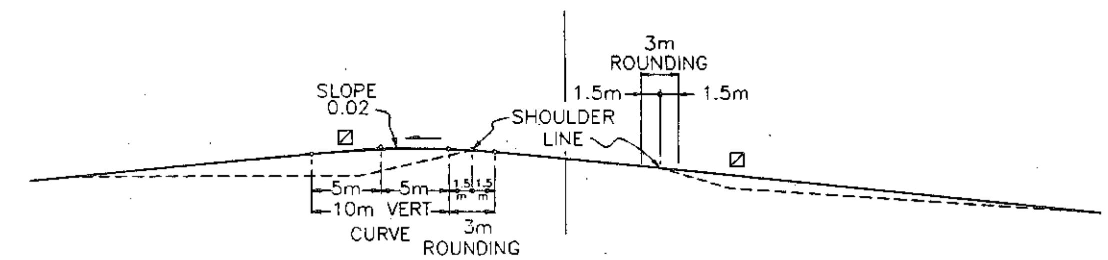
PUBLIC APPROACHES AND ENTRANCES TO BUILDINGS OR RESIDENCES SHALL BE PAVED 15m OUT FROM EDGE OF SHOULDER OR TO THE RIGHT-OF-WAY LINE, WHICHEVER IS LESS. FIELD ENTRANCES SHALL BE PAVED 1.2m OUT FROM EDGE OF SHOULDER. STABILIZATION THICKNESSES SHALL BE AS SHOWN ON THE PLANS.



STANDARD CROWNED SECTION



SUPERELEVATED CUT SECTION



SUPERELEVATED FILL SECTION

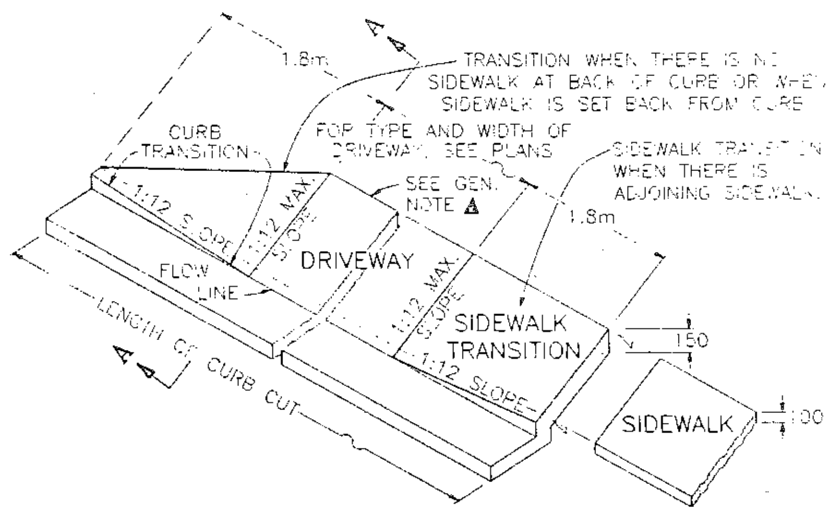
VERTICAL ALIGNMENT SIDE APPROACH ROADS INTERSECTING MAIN ROADWAY

☒ TANGENT SLOPE NOT STEEPER THAN 10%. BEYOND V.C., THE SLOPE MAY BE STEEPER, IF REQUIRED, TO MEET EXISTING APPROACH SLOPE.

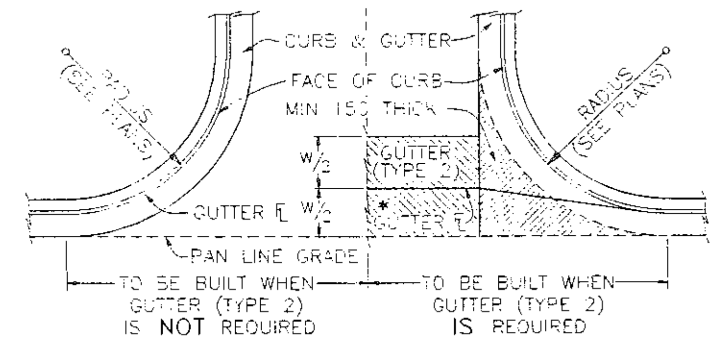
COLORADO
DEPARTMENT OF TRANSPORTATION

APPROACH ROADS

DATE REVISED	ISSUED BY STAFF DESIGN BRANCH DATE:	STANDARD PLAN NO. M-203-1 SHEET 1 OF 1



CURB CUT FOR DRIVEWAYS



▨ THIS AREA SHALL BE POURED MONOLITHICALLY WITH CURB AND GUTTER AND PAID FOR AS "CONCRETE PAVEMENT."

* FLOW LINE LOCATION WILL BE ESTABLISHED BY W/2 SHOWN ON PLANS.

CONSTRUCTION OF CONCRETE GUTTERS AT INTERSECTION

LEGEND FOR RADII
A = 3 TO 6
B = 25
C = 40
D = 40 TO 50

GENERAL NOTES

ON CURVES HAVING A RADIUS OF 600m OR LESS, CURBS AND OR GUTTERS ARE TO BE PLACED ON THE ARC OF THE CURVE UNLESS OTHERWISE NOTED ON PLANS. A MAXIMUM CORD LENGTH OF 3m MAY BE USED WHEN THE RADIUS IS GREATER THAN 600m.

▲ — EXPANSION JOINTS SHALL BE INSTALLED WHEN ABUTING EXISTING CONCRETE OR FIXED STRUCTURE. EXPANSION JOINT MATERIAL SHALL BE 13mm THICK AND SHALL EXTEND THE FULL DEPTH OF THE CONTACT SURFACE.

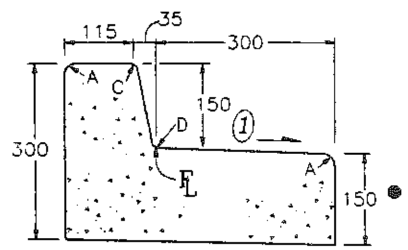
CONCRETE SHALL BE CLASS A OR B.

(1) — GUTTER CROSS SLOPES SHALL BE 0.04 m/m WHEN DRAING AWAY FROM CURB AND 0.02 m/m WHEN DRAING TOWARD CIRB.

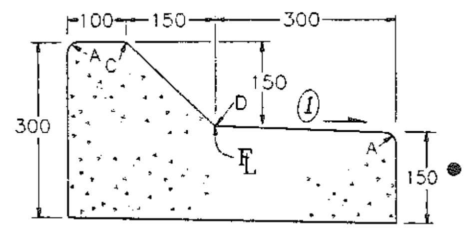
PROFILE GRADE OF CURBS AND GUTTERS SHALL BE LOCATED AT THE FLOW LINE.

● — WHEN TIE BARS ARE REQUIRED, THE GUTTER THICKNESS SHALL BE INCREASED TO THE PAVEMENT THICKNESS T. BARS SHALL BE EPOXY-COATED CONFORMING TO AASHTO M 284M AND SPACED 750. THEY SHALL BE INSERTED T/2 AND 1/2 LENGTH INTO THE GUTTER.

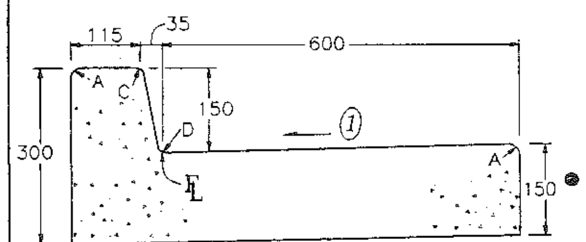
NOTE: ALL DIMENSIONS ARE MILLIMETERS (mm) UNLESS OTHERWISE NOTED.



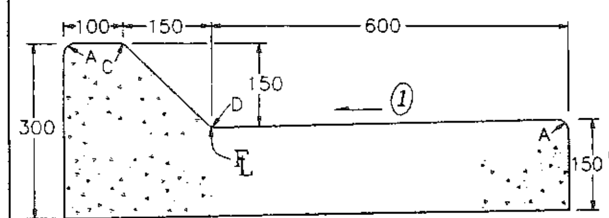
CURB AND GUTTER TYPE 2
(SECTION I B)
(150 BARRIER — 300 GUTTER)



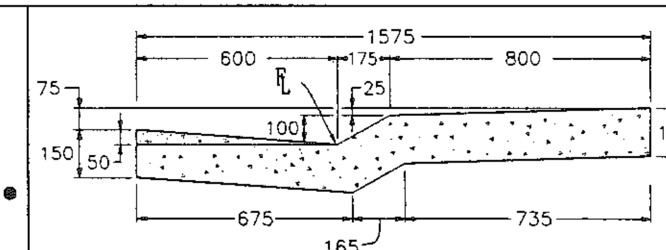
CURB AND GUTTER TYPE 2
(SECTION I M)
(150 MOUNTABLE — 300 GUTTER)



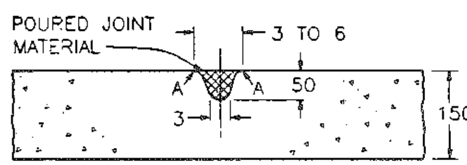
CURB AND GUTTER TYPE 2
(SECTION II B)
(150 BARRIER — 600 GUTTER)



CURB AND GUTTER TYPE 2
(SECTION II M)
(150 MOUNTABLE — 600 GUTTER)

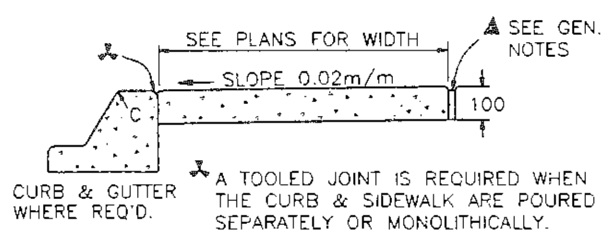


CURB AND GUTTER TYPE 2
(SECTION MS)
(100 MOUNTABLE WITH SIDEWALK)



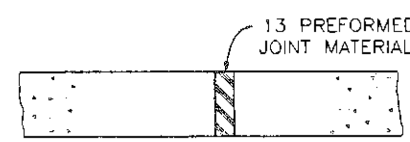
THIS JOINT REQUIRED WHERE LENGTH OF SLAB EXCEEDS 4.5m.

TRANSVERSE CONTRACTION JOINT FOR CONCRETE PAVEMENT (DRIVEWAYS)



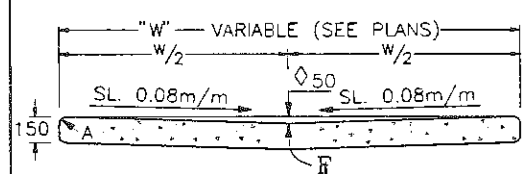
A TOOLED JOINT IS REQUIRED WHEN THE CURB & SIDEWALK ARE POURED SEPARATELY OR MONOLITHICALLY.

CONCRETE SIDEWALK



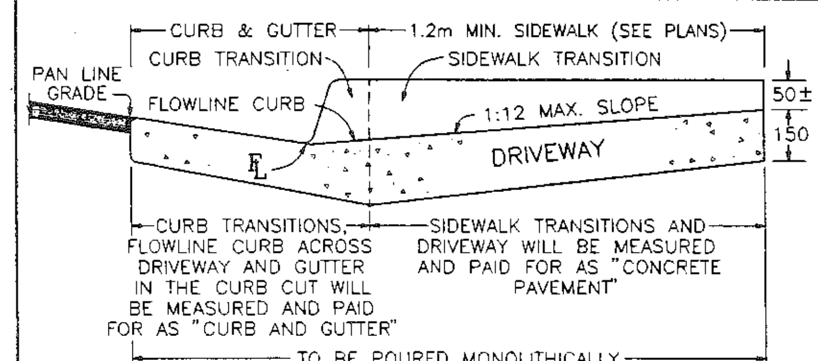
NOTE:
EXPANSION JOINTS SHALL BE PLACED IN THE SIDEWALK AT INTERVALS OF NOT MORE THAN 150m.

SIDEWALK EXPANSION JOINT



◊ 50 DEPTH WHEN USED AS A CROSSPAN IN AN INTERSECTION

GUTTER TYPE 2

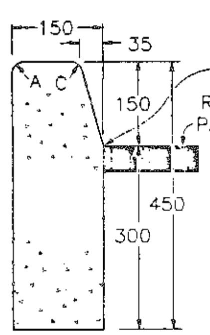


CURB TRANSITIONS, FLOWLINE CURB ACROSS DRIVEWAY AND GUTTER IN THE CURB CUT WILL BE MEASURED AND PAID FOR AS "CURB AND GUTTER"

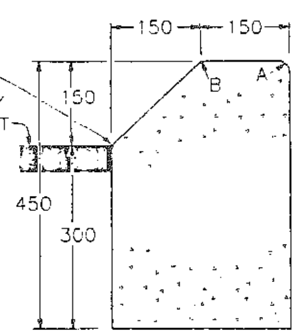
SIDEWALK TRANSITIONS AND DRIVEWAY WILL BE MEASURED AND PAID FOR AS "CONCRETE PAVEMENT"

TO BE POURED MONOLITHICALLY

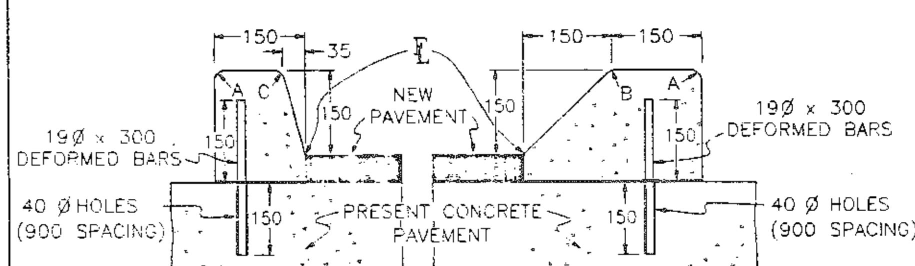
CONCRETE PAVEMENT (DRIVEWAYS)
SECTION A-A



CURB TYPE 2
(150 BARRIER)(SECTION B)



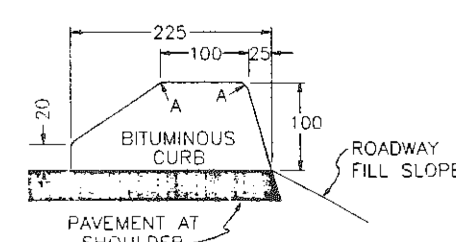
CURB TYPE 2
(150 MOUNTABLE)(SECTION M)



19Ø x 300 DEFORMED REINFORCING BARS AT 900 SPACING. BARS TO BE GROUTED IN 40 Ø HOLES IN PRESENT CONCRETE. GROUT TO CONSIST OF 2 PARTS CLEAN SAND AND 1 PART CEMENT. COST OF INSTALLATION IS TO BE INCLUDED IN THE PRICE BID FOR CURB.

CURB TYPE 4
(150 BARRIER)(SECTION B)

CURB TYPE 4
(150 MOUNTABLE)(SECTION M)

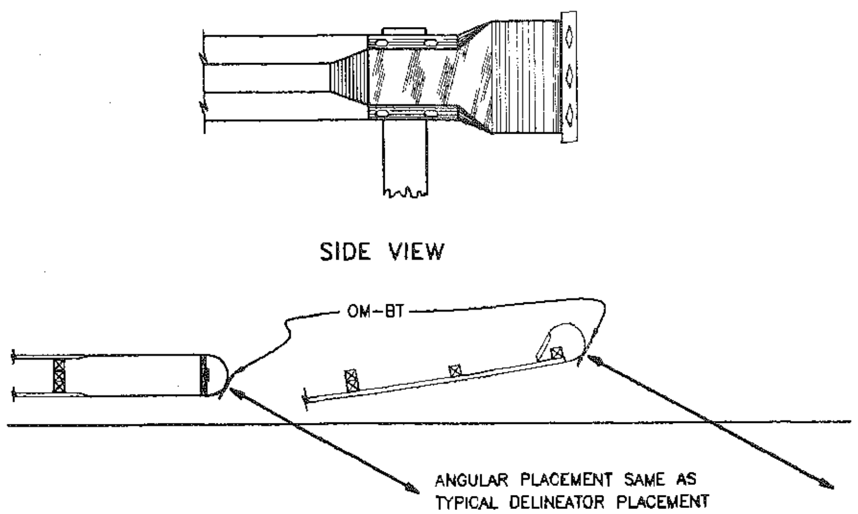


CURB TYPE 6
(100 MOUNTABLE)(SECTION M)

COLORADO DEPARTMENT OF TRANSPORTATION

CURBS AND GUTTERS

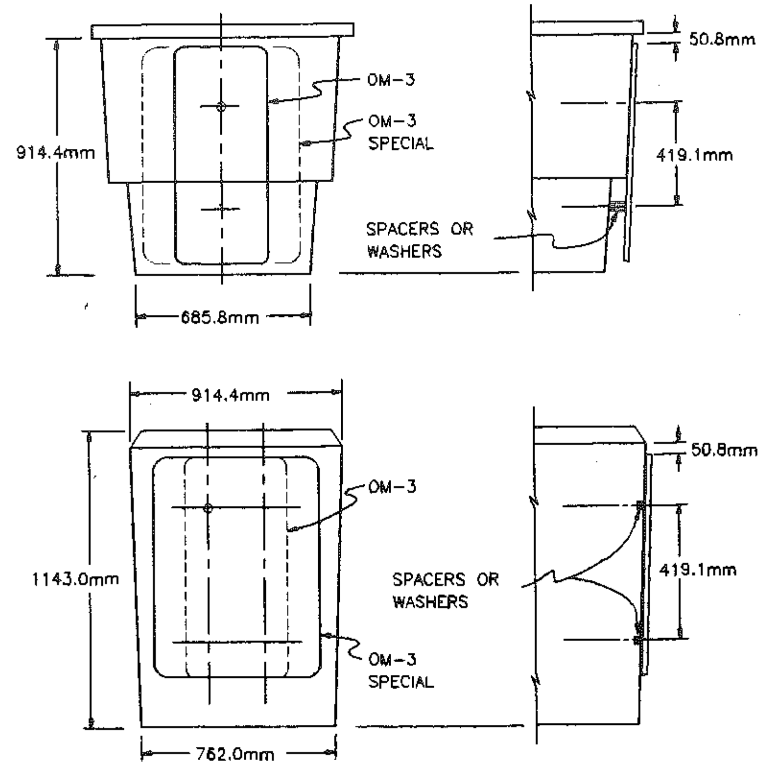
DATE REVISED	ISSUED BY STAFF DESIGN BRANCH DATE:	STANDARD PLAN NO. M-609-1 SHEET 1 OF 1



SIDE VIEW

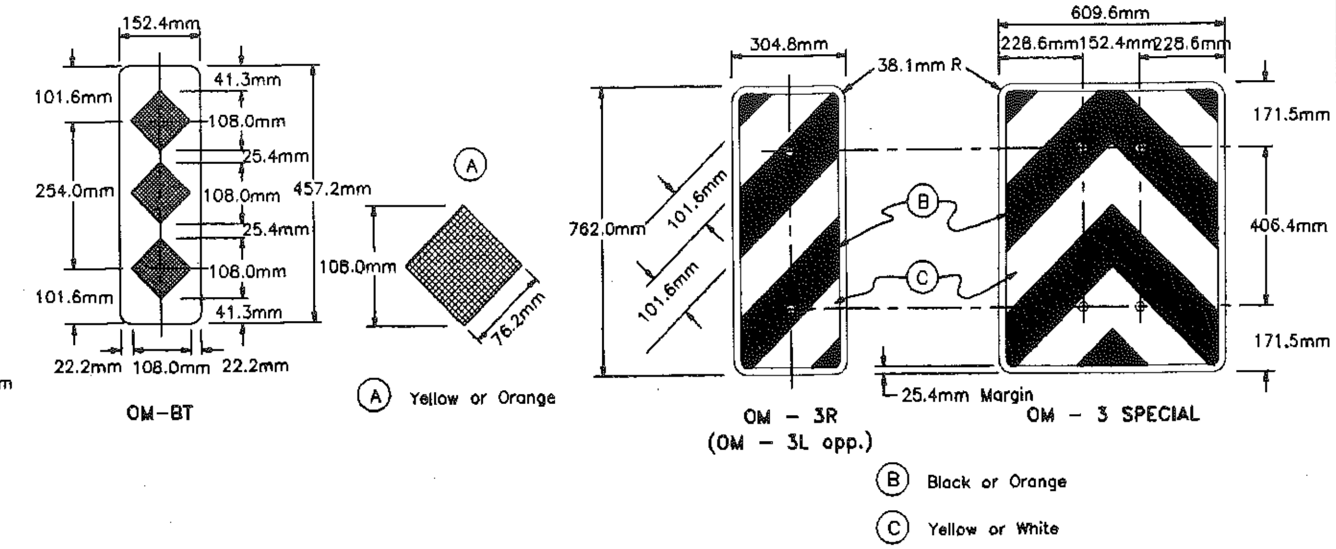
TOP VIEWS

BUFFER TERMINALS

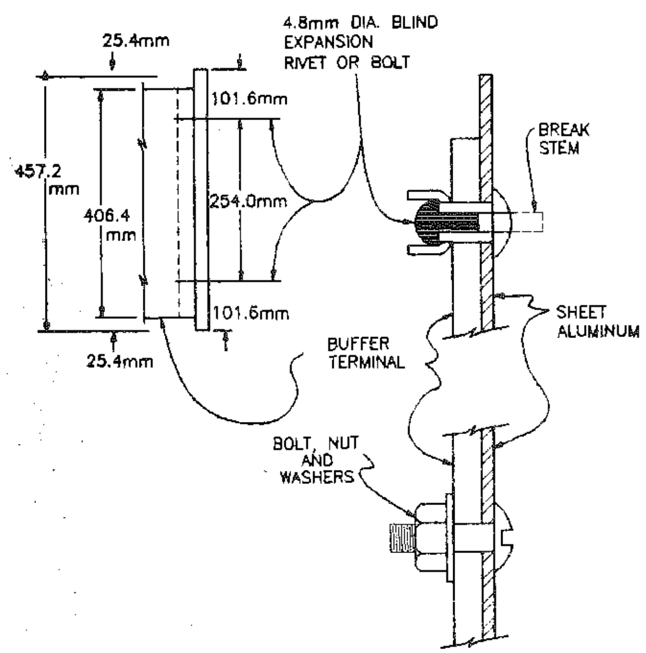


FRONT VIEWS SIDE VIEWS

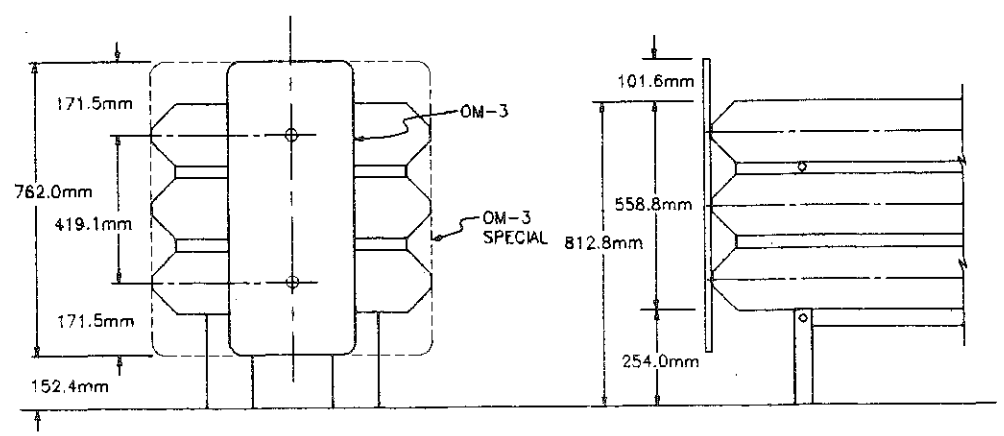
IMPACT ATTENUATOR (SAND FILLED)



SUPPLEMENTAL DELINEATION DETAILS

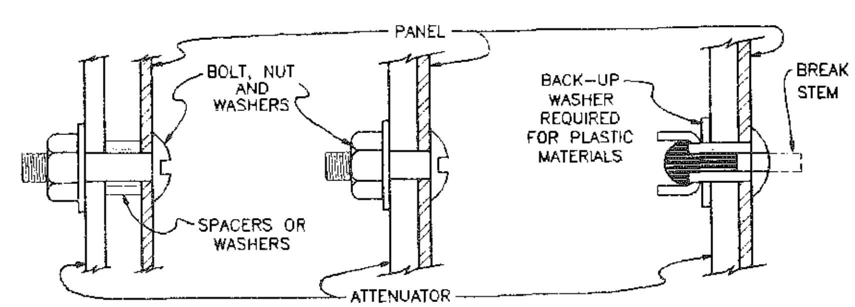


BUFFER
PANEL ATTACHMENT DETAILS



FRONT VIEW SIDE VIEW

IMPACT ATTENUATOR (MODULAR)



ATTENUATOR PANEL ATTACHMENT DETAILS

SUPPLEMENTAL PANEL NOTES

1. All supplemental delineation panels shall be single sheet aluminum, 2mm minimum thickness.
2. Panels shall be fastened directly to the buffer terminal or impact attenuator with 51 or 106mm dia. blind expansion rivets, or 51 or 106mm bolts, nuts and washers.

   Expansion rivets shall be domed head aluminum with aluminum break stem mandrel, and shall have a back-up washer when used with plastic materials.

   Bolts, nuts and washers shall be galvanized or cadmium plated.

   Spacers, or spacing washers shall be used as necessary for sand filled attenuators.
3. Reflective sheeting shall conform to ASTM D4956, Type III. The sheeting shall be yellow for permanent installations.
   - OM-BT panels shall have yellow diamonds directly applied (no background sheeting).
   - OM-3 panels shall have yellow sheeting background with stencil black stripes.

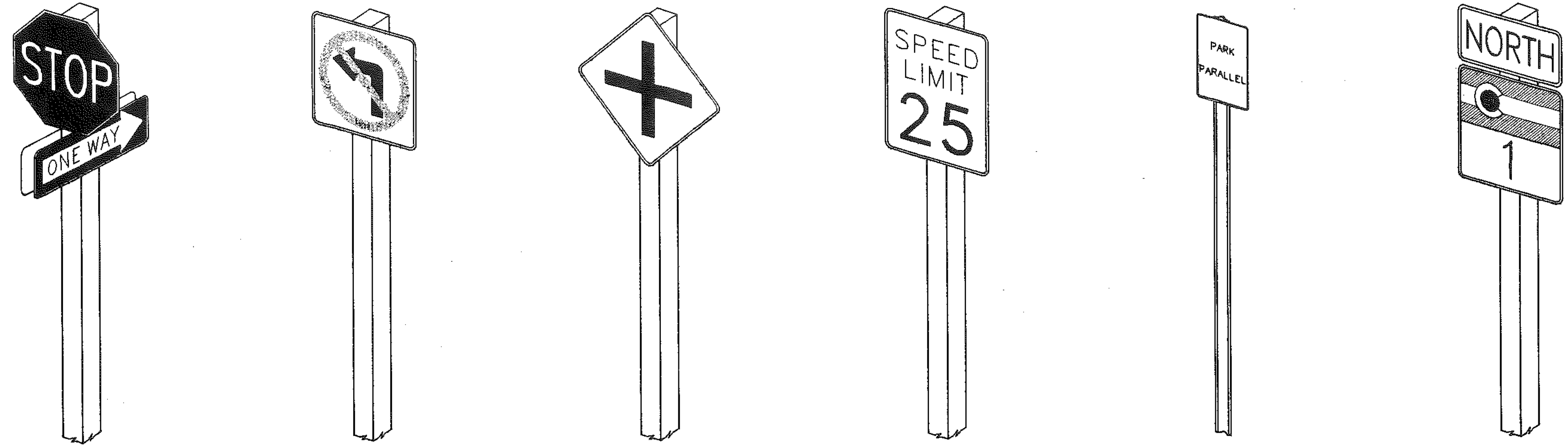
   The sheeting for temporary (construction zone) installations shall be as follows:
   - OM-BT panels shall have orange diamonds directly applied (no background sheeting).
   - OM-3 panels shall have alternating orange and white reflectorized stripes.
4. Supplemental delineation panels shall be included in the cost of the guardrail end anchor or the impact attenuator item.

SUPPLEMENTAL DELINEATION FOR GUARD RAIL BUFFER TERMINALS AND IMPACT ATTENUATORS

COLORADO DEPARTMENT OF TRANSPORTATION	
TYPICAL DELINEATOR INSTALLATIONS	
ISSUED BY STAFF TRAFFIC BRANCH	STANDARD PLAN NO. S-612-1
DATE:	SHEET 5 OF 5

DATE REVISED

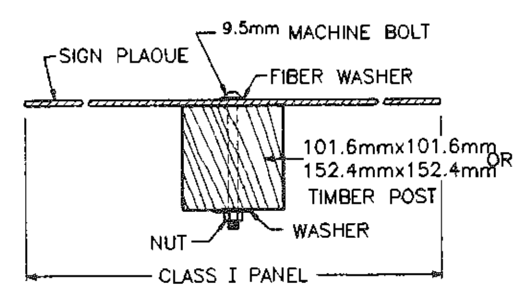
	REVISIONS	S-614-2	1/1
	METRIC CONVERSION BY H.K., 8/31/93		



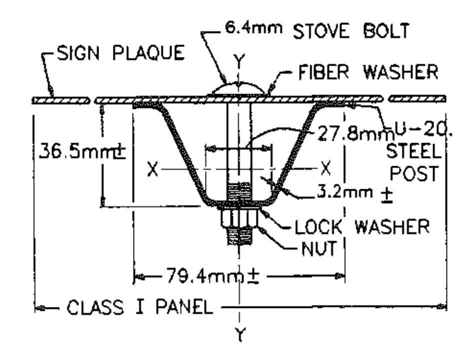
TYPICAL CLASS I GROUND SIGN INSTALLATIONS

GENERAL NOTES

1. ALL CLASS I SIGN PANELS SHALL BE SINGLE SHEET ALUMINUM, 0.25mm MINIMUM THICKNESS.
2. CLASS I SIGN PANELS SHALL BE FASTENED DIRECTLY TO THE POST. FASTEN TO U-20.0 POST WITH 57.2mm STOVE BOLTS AND TO TIMBER POSTS WITH 60.3mm MACHINE BOLTS. SEE STANDARD PLANS mmTYPICAL POLE MOUNT INSTALLATION" AND "TYPICAL MULTI-SIGN INSTALLATIONS" FOR EXCEPTIONS.
3. A FIBER WASHER SHALL BE PLACED BETWEEN THE BOLT HEAD AND THE FACE OF THE SIGN PANEL. A WASHER WHICH HAS A MINIMUM 1613mm^2 BEARING SURFACE MINUS THE HOLE SHALL BE PLACED UNDER THE NUT ON THE BACK OF A TIMBER POST.
4. BOLTS, NUTS AND METAL WASHERS SHALL BE GALVANIZED OR CADMIUM PLATED.
5. ALL SIGNS SHALL BE FABRICATED USING RETROREFLECTIVE SHEETING CONFORMING TO ASTM D4956. THE TYPE SHALL BE AS DESCRIBED IN THE STANDARD SPECIFICATIONS AND/OR AS SHOWN ON THE PLANS.
6. FOR SIGN PLACEMENT SEE "TYPICAL GROUND SIGN PLACEMENT" STANDARD.
7. STEEL POSTS SHALL BE A UNIFORM FLANGED CHANNEL SECTION (U-SHAPE) MADE FROM HOT ROLLED STRUCTURAL STEEL, RE-ROLLED RAIL STEEL, OR NEW BILLET STEEL HAVING A MINIMUM YIELD STRENGTH OF AT LEAST 206,820 KN/M^2 AND A MINIMUM TENSILE STRENGTH OF AT LEAST 344,700 KN/M^2. U-2 POSTS SHALL WEIGH 29.18 N/M EXCEPT THAT A MILL TOLERANCE OF MINUS 3½% OF THE WEIGHT OF ANY ONE POST WILL BE ALLOWED. ALTERNATE POSTS WILL BE ACCEPTABLE IF THE SECTION MODULUS IS AT LEAST 3280 mm^3 ABOUT THE X-X AXIS AND AT LEAST 4100 mm^3 ABOUT THE Y-Y AXIS. COLOR OF POSTS SHALL BE INTERSTATE GREEN. POSTS SHALL HAVE 7.9mm HOLES DRILLED OR PUNCHED ON 25.4mm OR 50.8mm CENTERS FOR THE TOP 12.2 METER OF THE POST AS A MINIMUM WITH THE FIRST HOLE 38.1mm FROM THE TOP OF THE POST.
8. FOR ADDITIONAL INFORMATION, REFER TO "TABULATION OF SIGNS". TIMBER POSTS SHALL BE 101.6mm x 101.6mm OR 152.4mm X 152.4mm AS NOTED THEREIN AND SHALL CONFORM TO STANDARD DRESSED (S40.0S) SIZES.
9. VERTICAL SPACING BETWEEN PANELS ON THE SAME POST SHALL BE 25.4mm MINIMUM TO 38.1mm MAXIMUM.



TYPICAL TIMBER POST SECTION

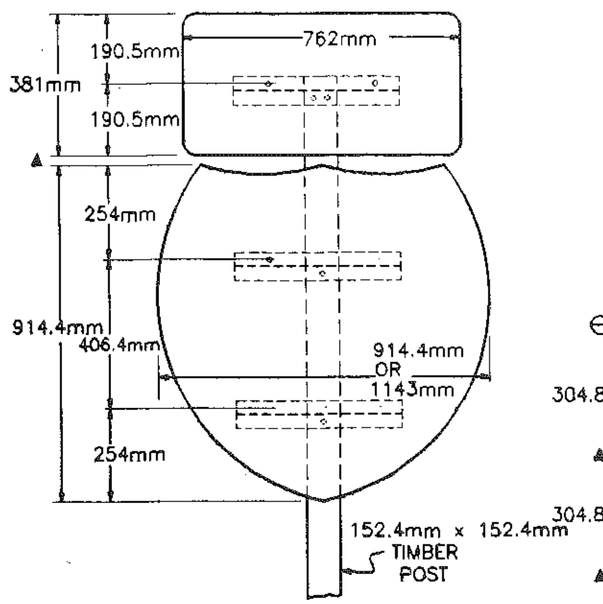


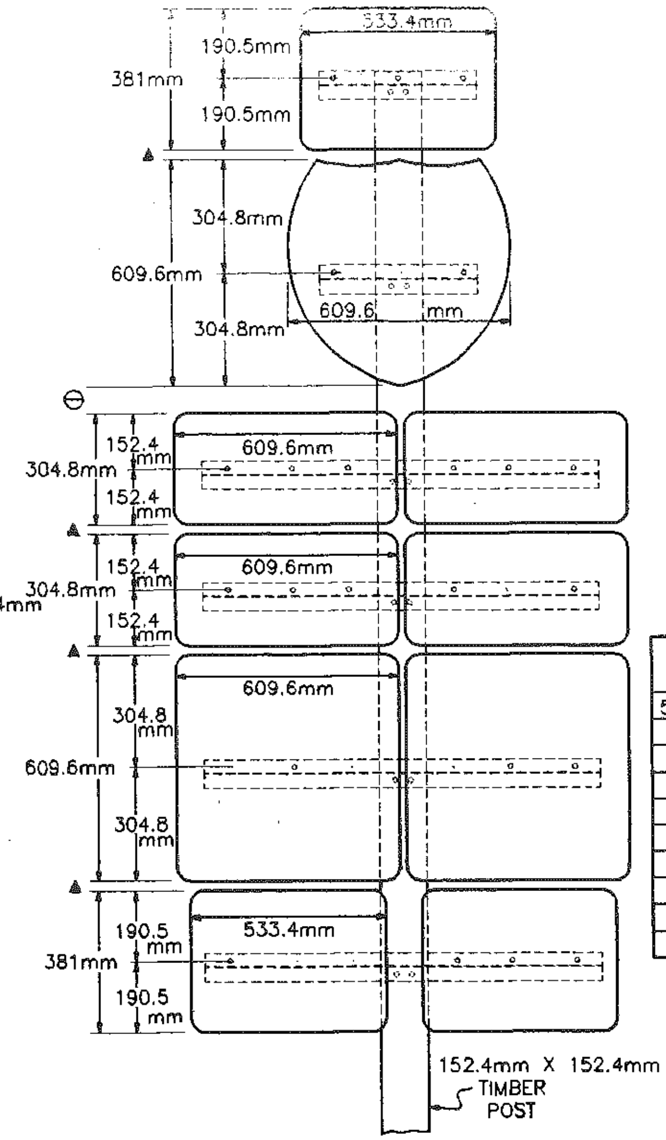
TYPICAL U-2 POST SECTION

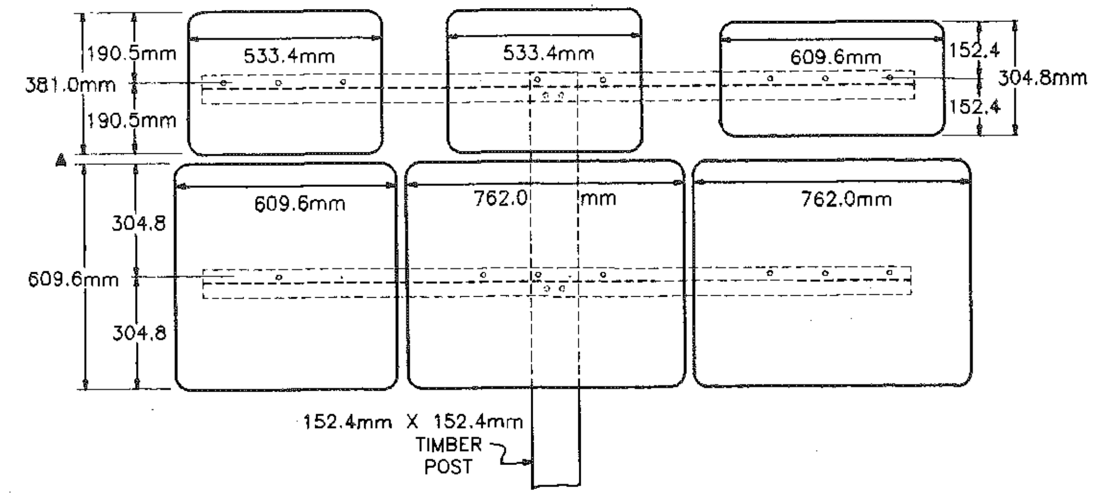
COLORADO DEPARTMENT OF TRANSPORTATION	
CLASS I GROUND SIGN INSTALLATIONS	
ISSUED BY STAFF TRAFFIC BRANCH	STANDARD PLAN NO. **S-614-2**
DATE REVISED / DATE:	SHEET 1 OF 1

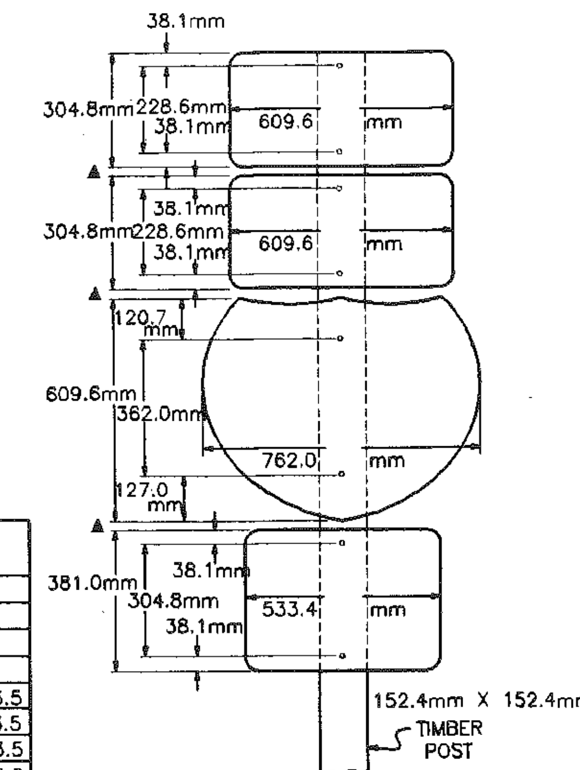
REVISIONS
METRIC CONVERSION BY H.K., 8/30/93

S-614-10



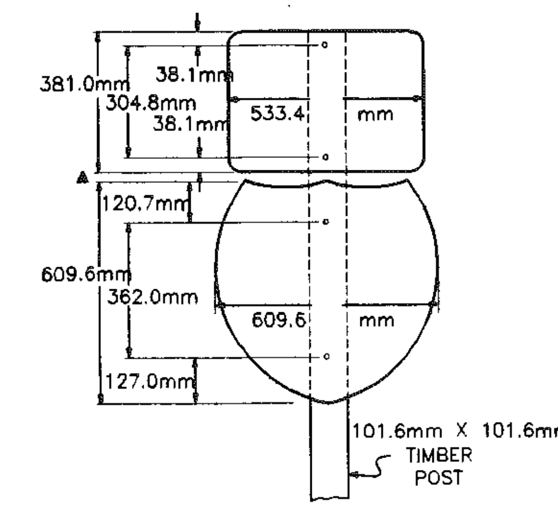


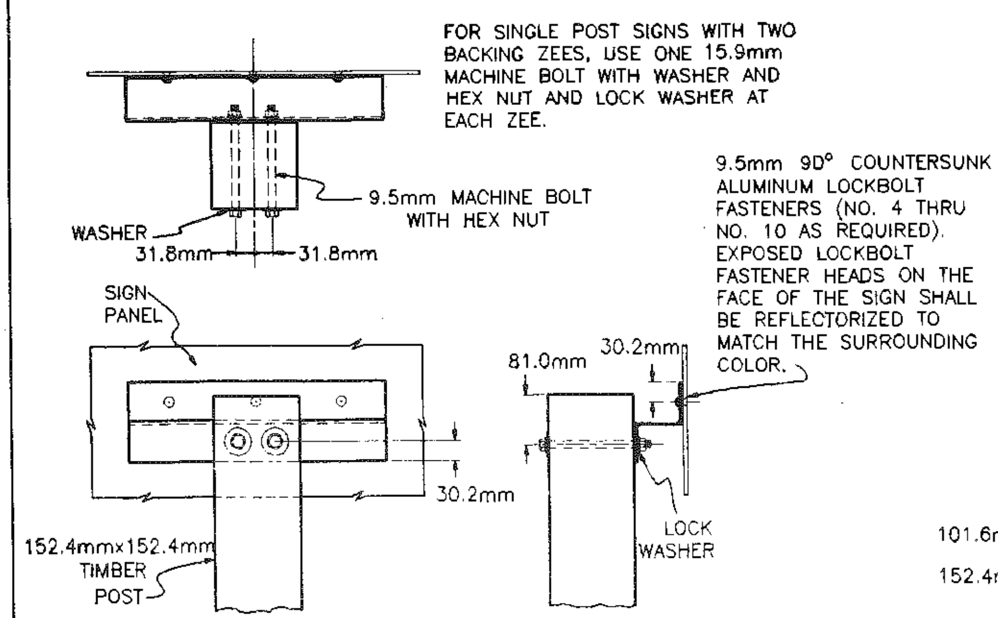




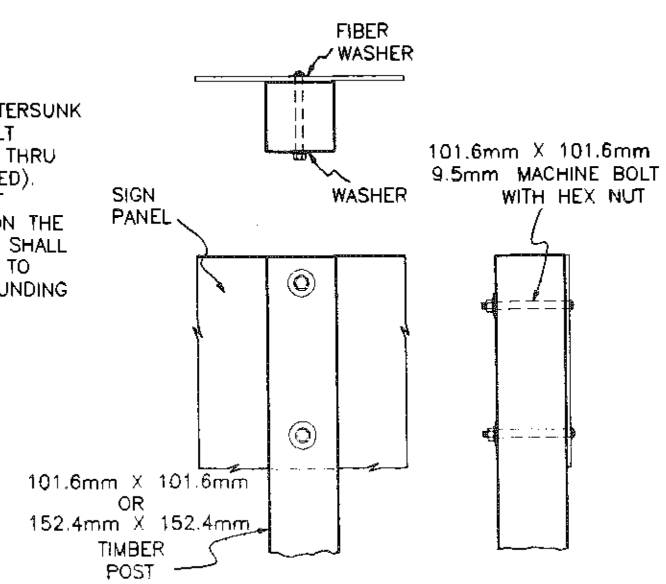
PANEL COMBINATIONS**	ZEE** LENGTH	HOLE SPACING**
533.4 , 609.6 , 762 , 914.4 , 1143	431.8	63.5 , 152.4 , 152.4 , 63.5
609.6 & 609.6	1066.8	63.5 , 152.4 , 152.4 , 330.2 , 152.4 , 152.4 , 63.5
609.6 & 762.0	1143.0	63.5 , 152.4 , 152.4 , 406.4 , 152.4 , 152.4 , 63.5
762.0 & 762.0	1219.2	63.5 , 152.4 , 152.4 , 482.6 , 152.4 , 152.4 , 63.5
609.6 & 609.6 & 609.6	1701.8	63.5, 152.4, 152.4, 330.2, 152.4, 152.4, 330.2, 152.4, 152.4, 63.5
609.6 & 609.6 & 762.0	1778.0	63.5, 152.4, 152.4, 330.2, 152.4, 152.4, 406.4, 152.4, 152.4, 63.5
609.6 & 762.0 & 609.6	1854.2	63.5, 152.4, 152.4, 406.4, 152.4, 152.4, 406.4, 152.4, 152.4, 63.5
762.0 & 609.6 & 762.0	1854.2	63.5, 152.4, 152.4, 406.4, 152.4, 152.4, 406.4, 152.4, 152.4, 63.5
609.6 & 762.0 & 762.0	1930.4	63.5, 152.4, 152.4, 406.4, 152.4, 152.4, 482.6, 152.4, 152.4, 63.5
762.0 & 762.0 & 762.0	2006.6	63.5, 152.4, 152.4, 482.6, 152.4, 152.4, 482.6, 152.4, 152.4, 63.5

** ALL DIMENSIONS ARE IN MILLIMETER





CLASS II MARKER
ASSEMBLY INSTALLATION



CLASS I MARKER
ASSEMBLY INSTALLATION

GENERAL NOTES

1. FOR SIGN PLACEMENT, SEE "TYPICAL GROUND SIGN
2. ROUTE MARKERS SHALL BE SINGLE SHEET ALUMINUM 2.54mm MINIMUM THICKNESS.
3. TIMBER POSTS SHALL BE 101.6mmX101.6mm OR 152.4mmX152.4mm AS NOTED INTHE "TABULATION OF SIGNS" AND SHALL COMFORM TO STANDARD DRESSED (S4S) SIZES.
4. BACKING ZEES ARE 76.2mm X 68.3mm X 59.2mm 6061-T6 ALUMINUM ALLOY WEIGHING 34 N PER METER.
5. ALL SIGNS SHALL BE FABRICATED USING RETROREFLECTIVE SHEETING CONFORMING TO ASTM D4956. THE TYPE SHALL BE AS DESCRIBED IN THE STANDARD SPECIFICATIONS AND/OR AS SHOWN ON THE PLANS.
6. ▲ VERTICAL SPACING BETWEEN PANELS SHALL BE 25.4mm MINIMUM TO 38.1mm MAXIMUM.
7. ⊖ VERTICAL SPACING BETWEEN GROUPS OF PANELS SHALL BE 100.8mm.
8. BOLTS, NUTS, AND METAL WASHERS SHALL BE GALVANIZED OR CADMIUM PLATED.
9. ZEE LENGTH AND HOLE SPACING FOR AUXILIARY MARKERS TO BE THE SAME AS FOR CORRESPONDING ROUTE MARKERS.
10. WASHERS ON TIMBER POSTS SHALL HAVE 4033mm^2 OF BEARING SURFACE MINUS THE HOLE.

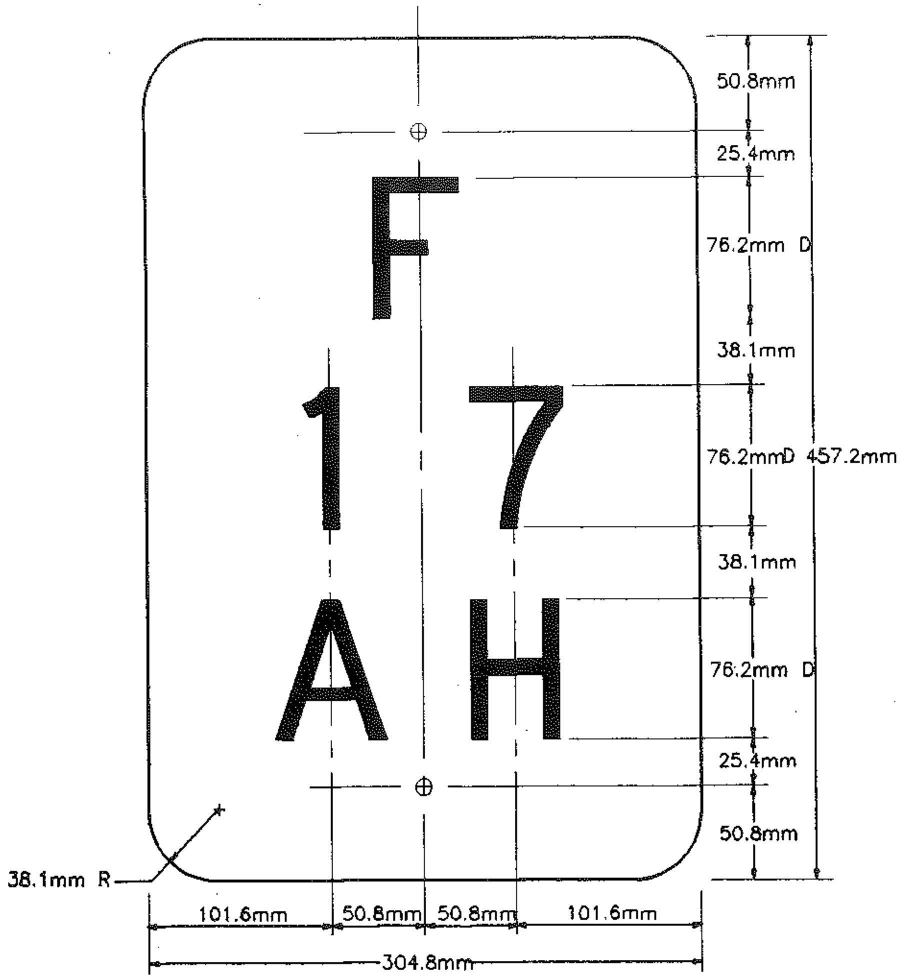
DATE REVISED	

COLORADO
DEPARTMENT OF TRANSPORTATION

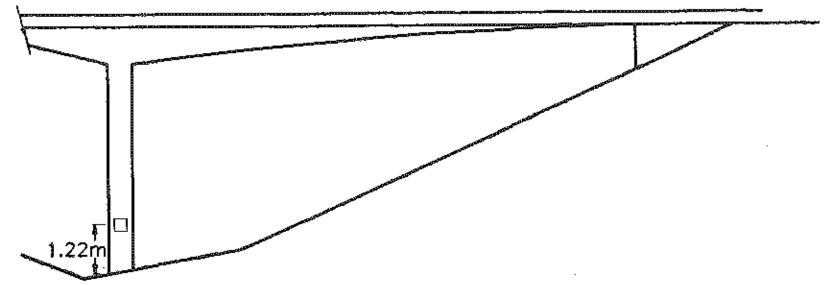
TYPICAL MARKER ASSEMBLY INSTALLATIONS

ISSUED BY STAFF TRAFFIC BRANCH	STANDARD PLAN NO. S-614-10
DATE:	SHEET 1 OF 1

REVISIONS	S-614-12
	METRIC CONVERSION BY H.K., 8/81/93



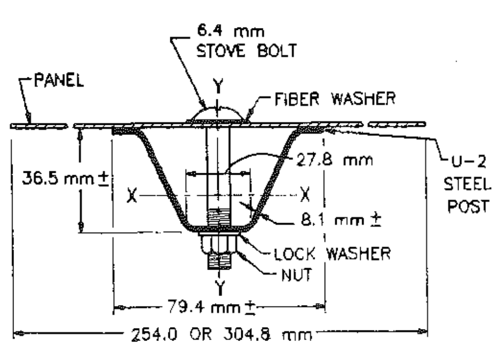
STRUCTURE IDENTIFICATION PANEL



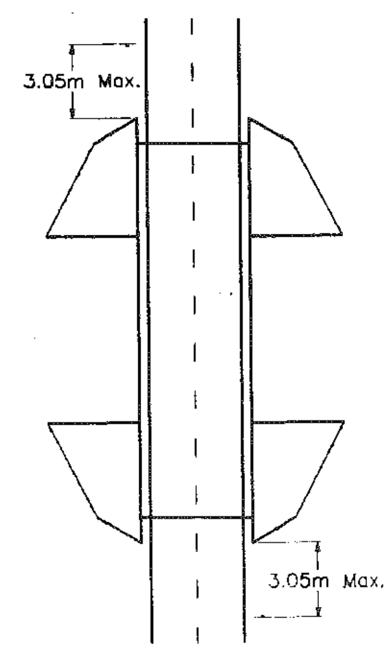
STRUCTURE NUMBER LOCATION ON PIERS

GENERAL NOTES

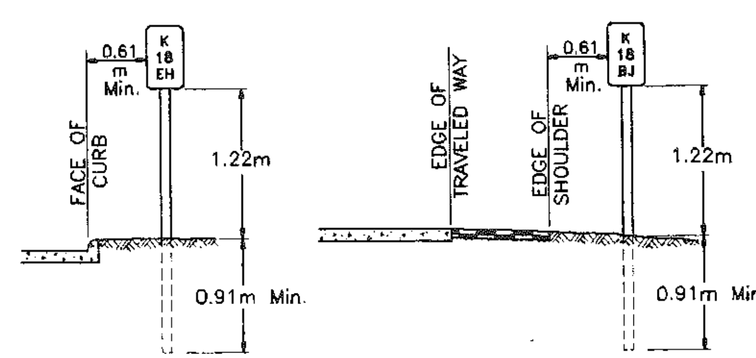
1. SIGN PANEL SHALL BE FABRICATED FROM SINGLE SHEET ALUMINUM 2.5mm MINIMUM THICKNESS.
2. STEEL POSTS SHALL BE A UNIFORM FLANGED CHANNEL SECTION (U-SHAPE) MADE FROM HOT ROLLED STRUCTURAL STEEL, RE-ROLLED RAIL STEEL, OR NEW BILLET STEEL HAVING A MINIMUM YIELD STRENGTH OF AT LEAST 2.067 N/m^2 AND A MINIMUM TENSILE STRENGTH OF AT LEAST 3.445 N/m^2. U-2 POSTS SHALL WEIGH 29.19 N/m EXCEPT THAT A MILL TOLERANCE OF MINUS 3½% OF THE WEIGHT OF ANY ONE POST WILL BE ALLOWED. ALTERNATE POSTS WILL BE ACCEPTABLE IF THE SECTION MODULUS IS AT LEAST 3260 mm^3 ABOUT THE X-X AXIS AND AT LEAST 4100mm^3 ABOUT THE Y-Y AXIS. COLOR OF POSTS SHALL BE INTERSTATE GREEN. POSTS SHALL HAVE 7.9mm HOLES DRILLED OR PUNCHED ON 25.4mm OR 50.8mm CENTERS FOR THE TOP 1.22 METER OF THE POST AS AMINIMUM WITH THE FIRST HOLE 38.1mm FROM THE TOP OF THE POST.
3. SIGN PANEL SHALL BE FASTENED DIRECTLY TO THE POST WITH TWO 6.4mm GALVANIZED OR CADMIUM PLATED STOVE BOLTS. A PLASTIC FIBER OR NYLON WASHER SHALL BE PLACED BETWEEN THE BOLT HEAD AND THE FACE OF THE PANEL. A GALVANIZED OR CADMIUM PLATED LOCK WASHER SHALL BE PLACED UNDER THE NUT ON THE BACK OF THE POST.
4. THE STRUCTURE NUMBER IS SHOWN ON THE PLANS.
5. ALL SIGNS SHALL BE FABRICATED USING RETROREFLECTIVE SHEETING CONFORMING TO ASTM D4956. THE TYPE SHALL BE AS DESCRIBED IN THE STANDARD SPECIFICATIONS AND/OR AS SHOWN ON THE PLANS.
6. STRUCTURE NUMBER IDENTIFICATION SIGN WILL NOT BE PAID FOR SEPARATELY, BUT SHALL BE INCLUDED IN THE WORK.
7. IN ADDITION TO THE REQUIREMENTS STATED ABOVE, STRUCTURE NUMBERS FOR HIGHWAYS PASSING UNDER CROSSROADS ARE TO BE PLACED AT THE FOLLOWING POINTS:
   (A) FOR STRUCTURES OF THREE OR MORE SPANS, THE STRUCTURE NUMBER SHALL BE STENCILED, FACING TRAFFIC, ON THE OUTSIDE FACE OF THE END COLUMN OF THE RIGHT HAND PIER.
   (B) FOR TWO SPAN STRUCTURES, THE STRUCTURE NUMBER SHALL BE STENCILED, FACING TRAFFIC, ON THE OUTSIDE FACE OF EACH END COLUMN OF THE CENTER PIER.



TYPICAL FASTENER DETAILS



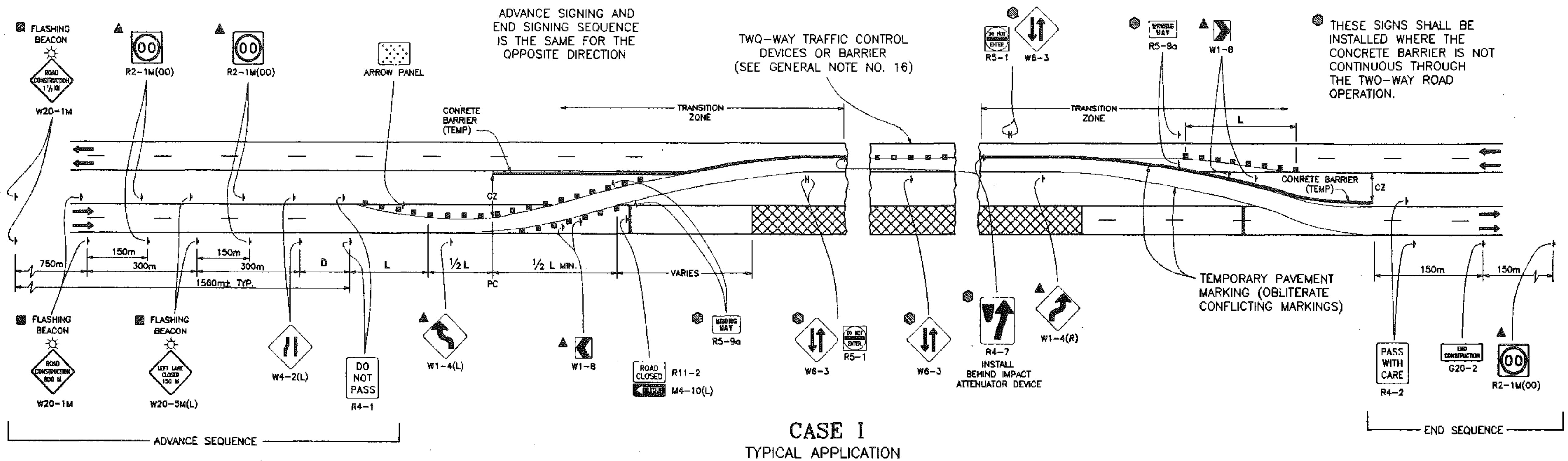
LOCATION DETAIL



LATERAL PLACEMENT DETAILS

COLORADO DEPARTMENT OF TRANSPORTATION	
STRUCTURE NUMBER INSTALLATION	
ISSUED BY STAFF TRAFFIC BRANCH	STANDARD PLAN NO. **S-614-12**
DATE:	SHEET 1 OF 1

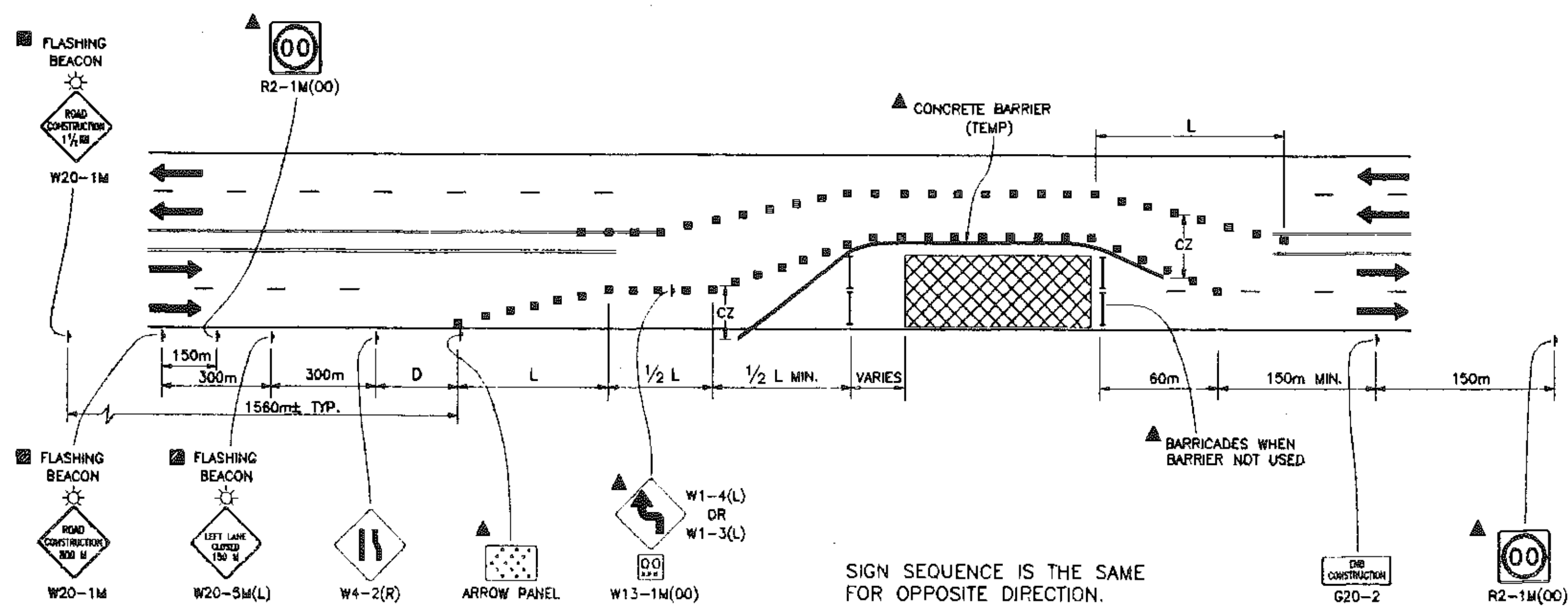
DATE REVISED



CASE I

TYPICAL APPLICATION

CLOSURE OF ONE ROADWAY 4-LANE DIVIDED HIGHWAY



CASE II

TYPICAL APPLICATION

CLOSURE OF HALF OF 4-LANE HIGHWAY, NOT PHYSICALLY DIVIDED

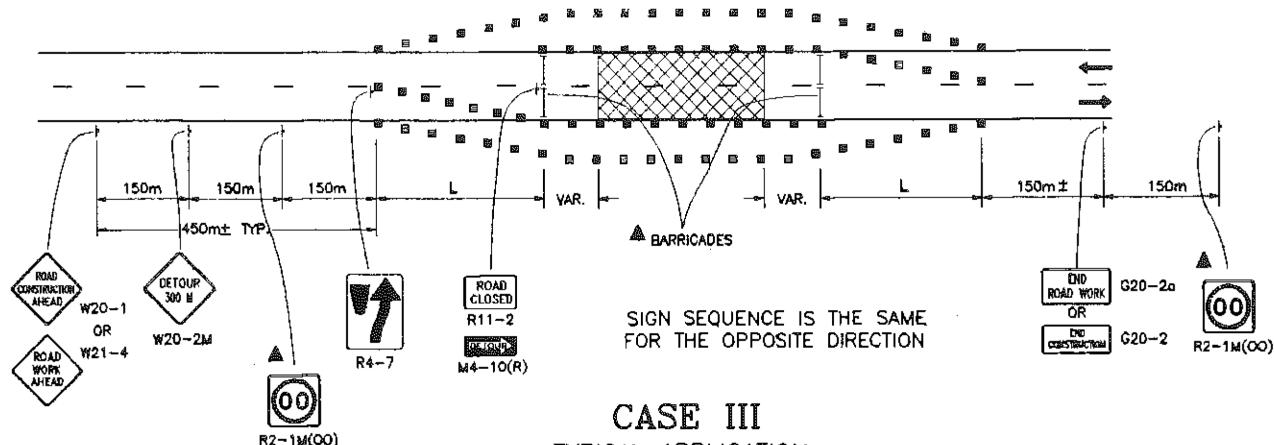
LEGEND

- ▪ CHANNELIZING DEVICE: FOR TYPE OF DEVICE TO BE USED, SEE THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES INCLUDED IN THE PLANS.
- TYPE 3 BARRICADE
- TYPE 1 OR 2 BARRICADE
- CONCRETE BARRIER (TEMPORARY)
- FLAGGER
- DIRECTION OF TRAVEL
- WORK AREA
- L TRANSITION TAPER LENGH:
  - L = MINIMUM LENGTH OF TAPER IN METERS
  - SPEED 45 MPH OR MORE: $L = S \times W$
  - SPEED 40 MPH OR LESS: $L = \frac{WS^2}{60}$
  - S = NUMERICAL VALUE OF SPEED LIMIT OR 85 PERCENTILE SPEED
  - W = WIDTH OF OFFSET IN METERS
- ADVANCE WARNING FLASHING OR SEQUENCING ARROW PANEL
- D SEE WARNING SIGN PLACEMENT TABLE FOR DISTANCE (CONDITION A).
- CZ CLEAR ZONE (SEE GENERAL NOTE 16).
- ▲ THESE DEVICES ARE OPTIONAL. THEIR NEED SHALL BE DETERMINED BY DETOUR DESIGN AND/OR SCOPE OF CONSTRUCTION ACTIVITY, AND ARE REQUIRED WHEN THEY ARE INCLUDED IN THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES.
- FLASHING BEACON IS OPTIONAL - SIGN IS REQUIRED.
- VARIES BUFFER SPACE (SEE GENERAL NOTE 21).

COLORADO DEPARTMENT OF TRANSPORTATION

TRAFFIC CONTROLS FOR HIGHWAY CONSTRUCTION

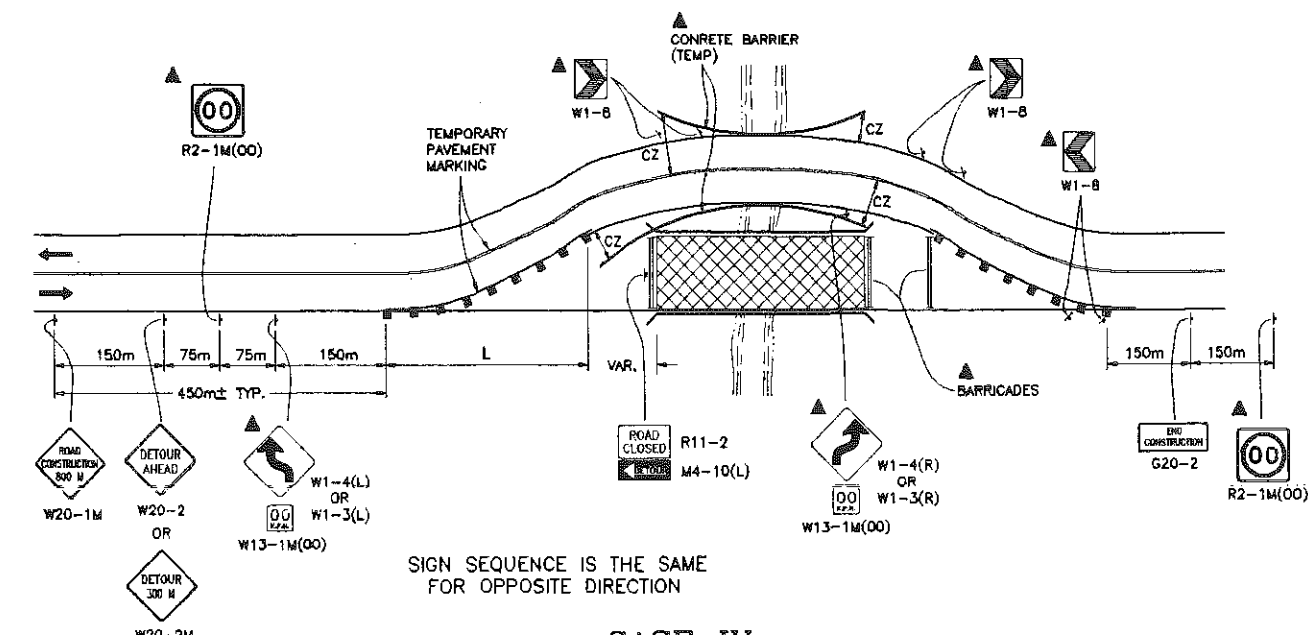
DATE REVISED	ISSUED BY STAFF TRAFFIC BRANCH DATE:	STANDARD PLAN NO. S-630-1 SHEET 1 OF 9



CASE III

TYPICAL APPLICATION

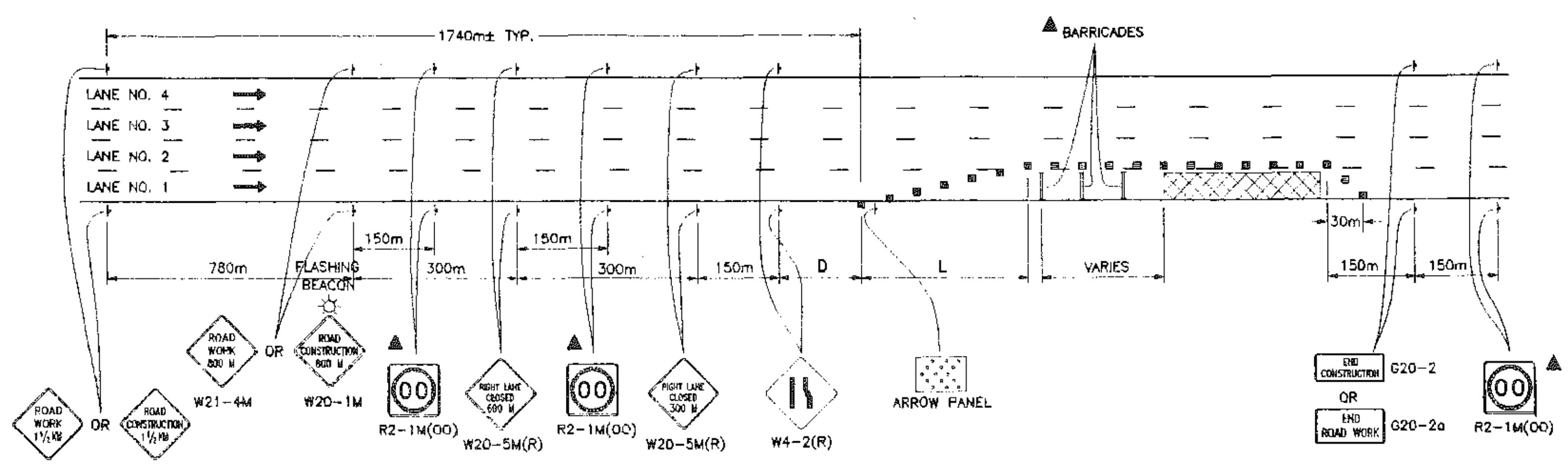
ROAD CLOSURE, USE OF ADJACENT SHOULDERS



CASE IV

TYPICAL APPLICATION

ROAD CLOSURE, BYPASS DETOUR PROVIDED



CASE V

TYPICAL APPLICATION

LANE 1 CLOSURE, MULTILANE FREEWAY

LEGEND

- CHANNELIZING DEVICE: FOR TYPE OF DEVICE TO BE USED, SEE THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES INCLUDED IN THE PLANS.
- TYPE 3 BARRICADE
- TYPE 1 OR 2 BARRICADE
- CONCRETE BARRIER (TEMPORARY)
- FLAGGER
- DIRECTION OF TRAVEL
- WORK AREA
- L TRANSITION TAPER LENGH:
  - L = MINIMUM LENGTH OF TAPER IN METERS
  - SPEED 45 MPH OR MORE: L = S x W
  - SPEED 40 MPH OR LESS: $L = \frac{WS^2}{60}$
  - S = NUMERICAL VALUE OF SPEED LIMIT OR 85 PERCENTILE SPEED
  - W = WIDTH OF OFFSET IN METERS
- ADVANCE WARNING FLASHING OR SEQUENCING ARROW PANEL
- D SEE WARNING SIGN PLACEMENT TABLE FOR DISTANCE (CONDITION A).
- CZ CLEAR ZONE (SEE GENERAL NOTE 16).
- ▲ THESE DEVICES ARE OPTIONAL. THEIR NEED SHALL BE DETERMINED BY DETOUR DESIGN AND/OR SCOPE OF CONSTRUCTION ACTIVITY, AND ARE REQUIRED WHEN THEY ARE INCLUDED IN THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES.
- FLASHING BEACON IS OPTIONAL - SIGN IS REQUIRED.
- VARIES BUFFER SPACE (SEE GENERAL NOTE 21).

COLORADO
DEPARTMENT OF TRANSPORTATION

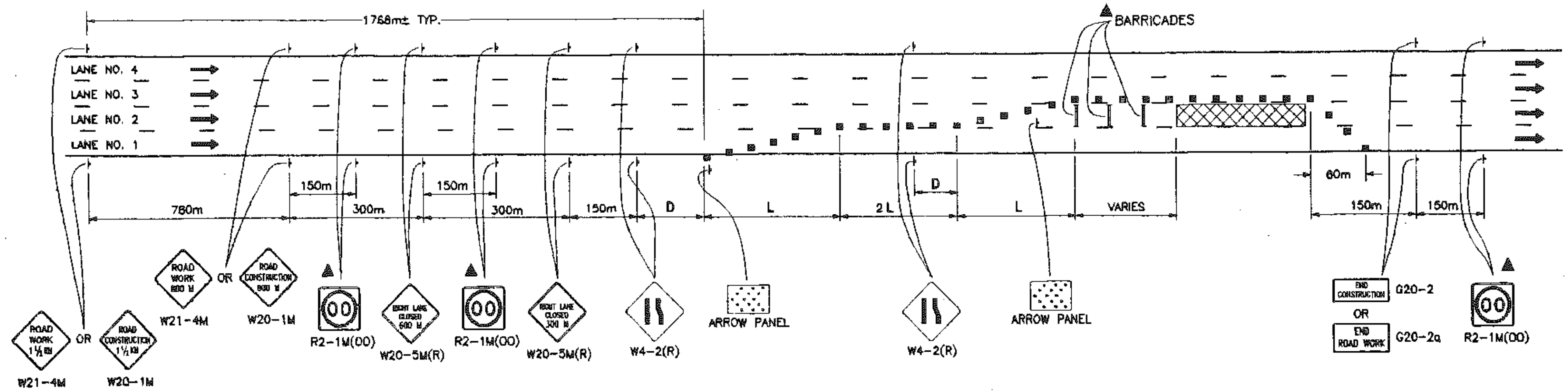
TRAFFIC CONTROLS FOR HIGHWAY CONSTRUCTION

ISSUED BY STAFF TRAFFIC BRANCH

DATE:

DATE REVISED

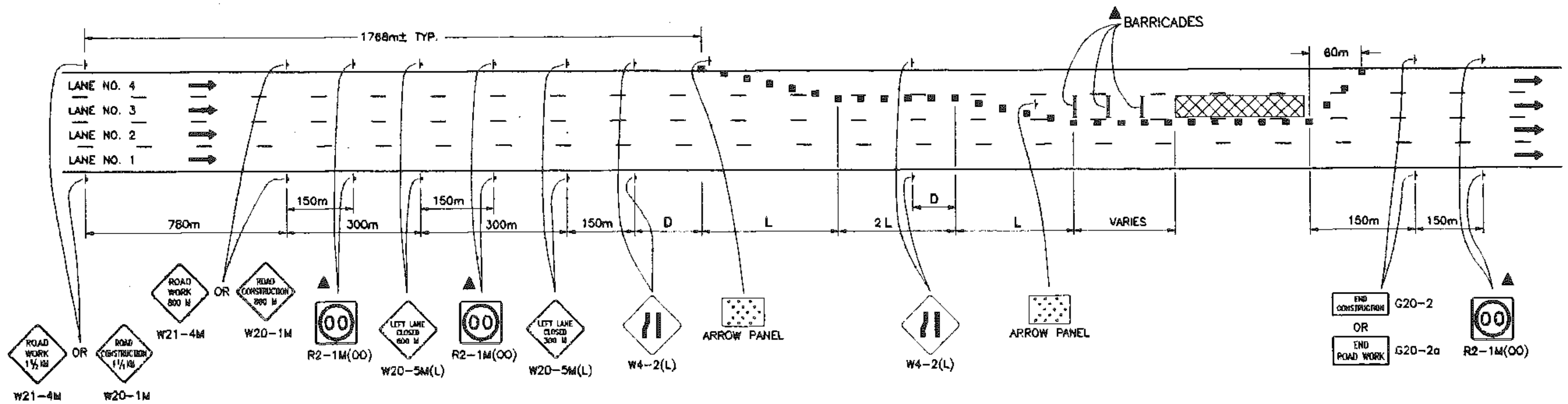
STANDARD PLAN NO. S-630-1



CASE VI

TYPICAL APPLICATION

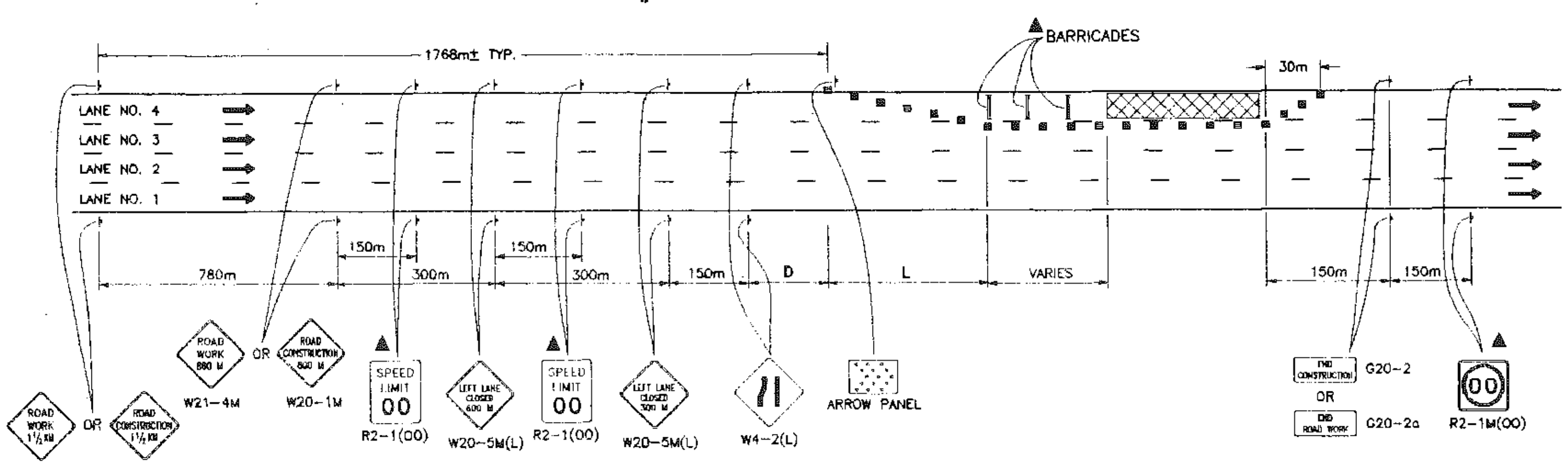
LANE #2 CLOSURE, MULTILANE FREEWAY



CASE VII

TYPICAL APPLICATION

LANE #3 CLOSURE, MULTILANE FREEWAY



CASE VIII

TYPICAL APPLICATION

LANE #4 CLOSURE, MULTILANE FREEWAY

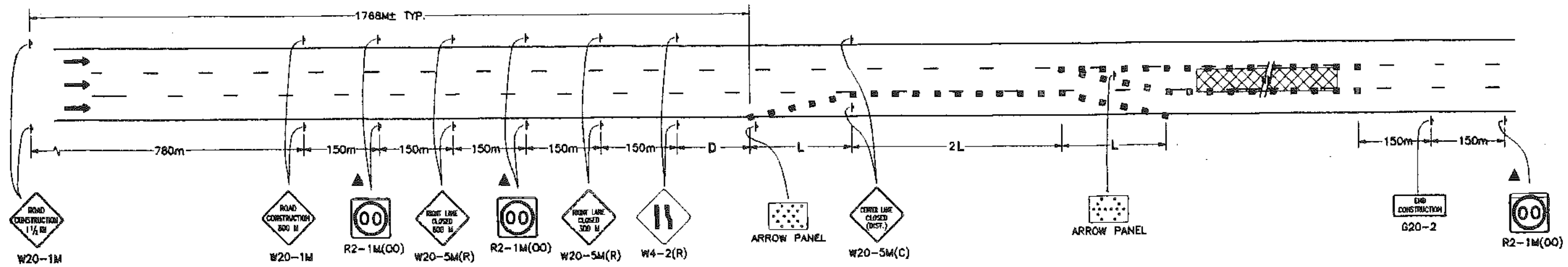
LEGEND

- ■ CHANNELIZING DEVICE: FOR TYPE OF DEVICE TO BE USED, SEE THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES INCLUDED IN THE PLANS.
- TYPE 3 BARRICADE
- TYPE 1 OR 2 BARRICADE
- CONCRETE BARRIER (TEMPORARY)
- FLAGGER
- DIRECTION OF TRAVEL
- WORK AREA
- L TRANSITION TAPER LENGH:
  - L = MINIMUM LENGTH OF TAPER IN METERS
  - SPEED 45 MPH OR MORE: L = S x W
  - SPEED 40 MPH OR LESS: $L = \frac{WS^2}{60}$
  - S = NUMERICAL VALUE OF SPEED LIMIT OR 85 PERCENTILE SPEED
  - W = WIDTH OF OFFSET IN METERS
- ADVANCE WARNING FLASHING OR SEQUENCING ARROW PANEL
- D SEE WARNING SIGN PLACEMENT TABLE FOR DISTANCE (CONDITION A).
- CZ CLEAR ZONE (SEE GENERAL NOTE 16).
- ▲ THESE DEVICES ARE OPTIONAL. THEIR NEED SHALL BE DETERMINED BY DETOUR DESIGN AND/OR SCOPE OF CONSTRUCTION ACTIVITY, AND ARE REQUIRED WHEN THEY ARE INCLUDED IN THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES.
- FLASHING BEACON IS OPTIONAL – SIGN IS REQUIRED.
- VARIES BUFFER SPACE (SEE GENERAL NOTE 21).

COLORADO
DEPARTMENT OF TRANSPORTATION

TRAFFIC CONTROLS FOR HIGHWAY CONSTRUCTION

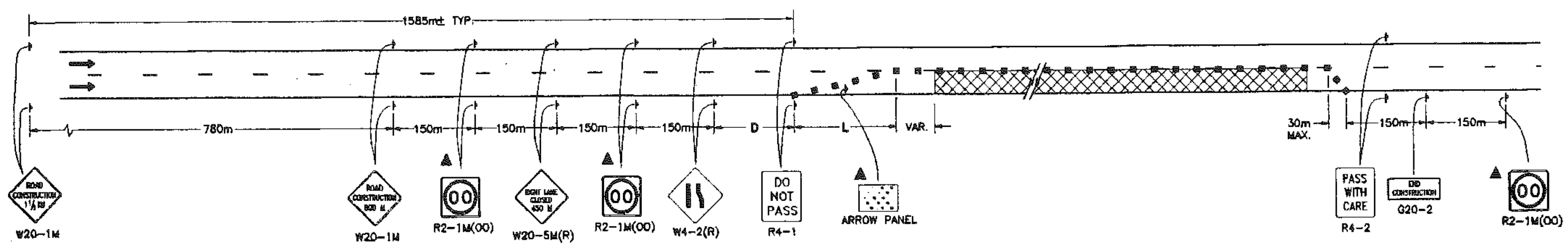
DATE REVISED	ISSUED BY STAFF TRAFFIC BRANCH	STANDARD PLAN NO.
	DATE:	S-630-1
		SHEET 3 OF 9



CASE IX

TYPICAL APPLICATION

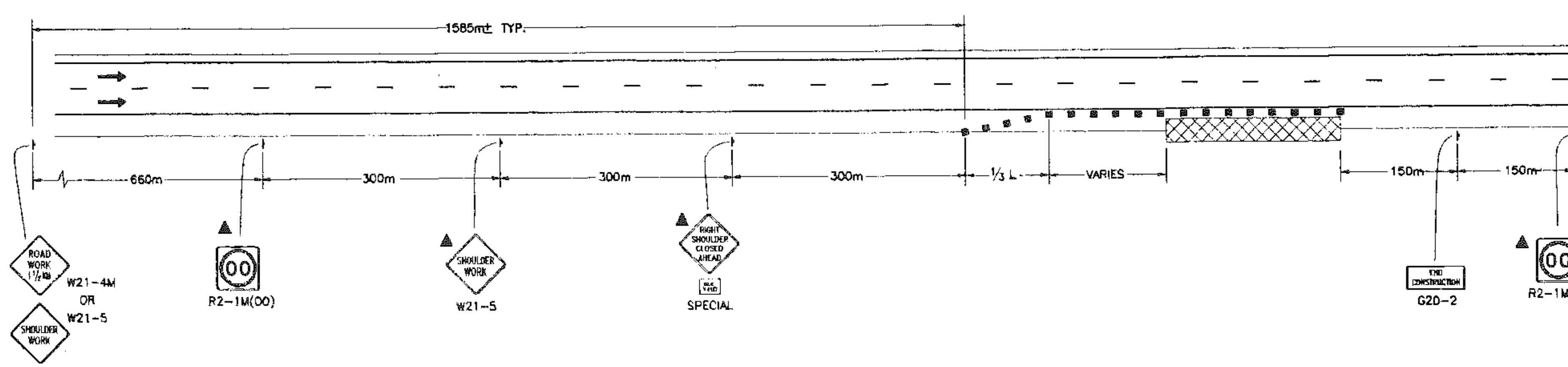
CENTER LANE CLOSURE – MULTILANE FREEWAY



CASE X

TYPICAL APPLICATION

ONE LANE CLOSED – FOUR-LANE DIVIDED HIGHWAY



CASE XI

TYPICAL APPLICATION

SHOULDER WORK – (FREEWAY/EXPRESSWAY)

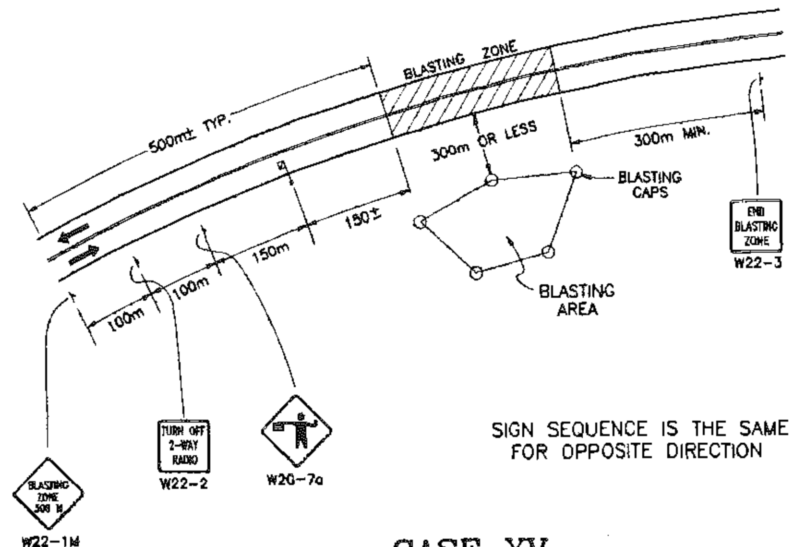
LEGEND

- ▪ CHANNELIZING DEVICE: FOR TYPE OF DEVICE TO BE USED, SEE THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES INCLUDED IN THE PLANS.
- TYPE 3 BARRICADE
- TYPE 1 OR 2 BARRICADE
- CONCRETE BARRIER (TEMPORARY)
- FLAGGER
- DIRECTION OF TRAVEL
- WORK AREA
- L TRANSITION TAPER LENGH:
  - L = MINIMUM LENGTH OF TAPER IN METERS
  - SPEED 45 MPH OR MORE: $L = S \times W$
  - SPEED 40 MPH OR LESS: $L = \frac{WS^2}{60}$
  - S = NUMERICAL VALUE OF SPEED LIMIT OR 85 PERCENTILE SPEED
  - W = WIDTH OF OFFSET IN METERS
- ADVANCE WARNING FLASHING OR SEQUENCING ARROW PANEL
- D SEE WARNING SIGN PLACEMENT TABLE FOR DISTANCE (CONDITION A).
- CZ CLEAR ZONE (SEE GENERAL NOTE 16).
- ▲ THESE DEVICES ARE OPTIONAL. THEIR NEED SHALL BE DETERMINED BY DETOUR DESIGN AND/OR SCOPE OF CONSTRUCTION ACTIVITY, AND ARE REQUIRED WHEN THEY ARE INCLUDED IN THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES.
- FLASHING BEACON IS OPTIONAL – SIGN IS REQUIRED.
- VARIES BUFFER SPACE (SEE GENERAL NOTE 21).

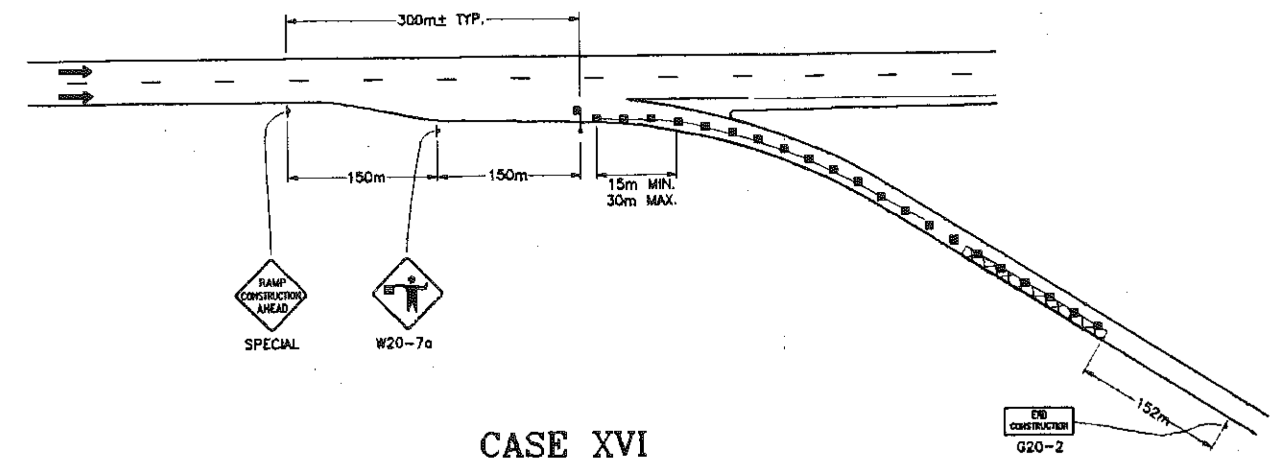
COLORADO DEPARTMENT OF TRANSPORTATION

TRAFFIC CONTROLS FOR HIGHWAY CONSTRUCTION

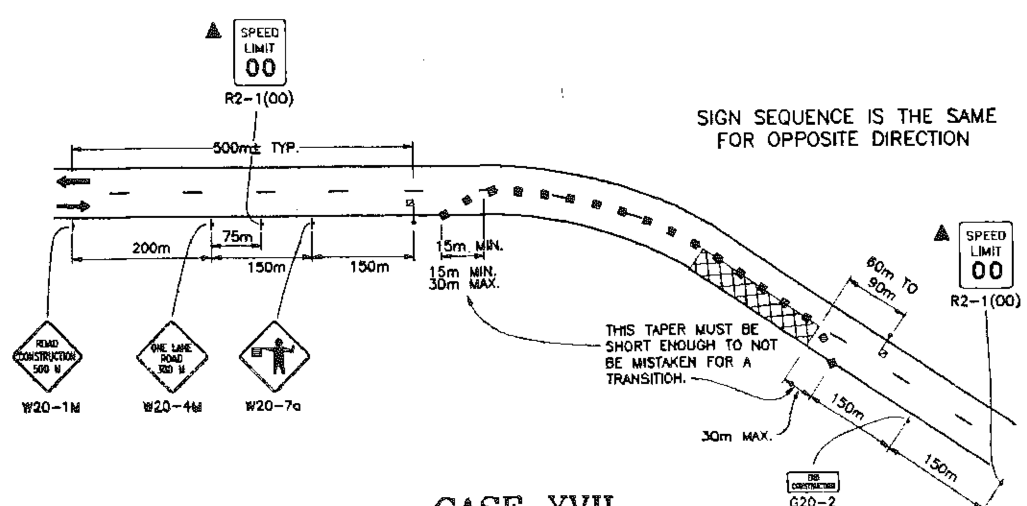
DATE REVISED	ISSUED BY STAFF TRAFFIC BRANCH DATE:	STANDARD PLAN NO. S-630-1 SHEET 4 OF 9



CASE XV
TYPICAL APPLICATION – FOR BLASTING



CASE XVI
TYPICAL APPLICATION
RAMP CONSTRUCTION WHERE PARTIAL RAMP IS CLOSED

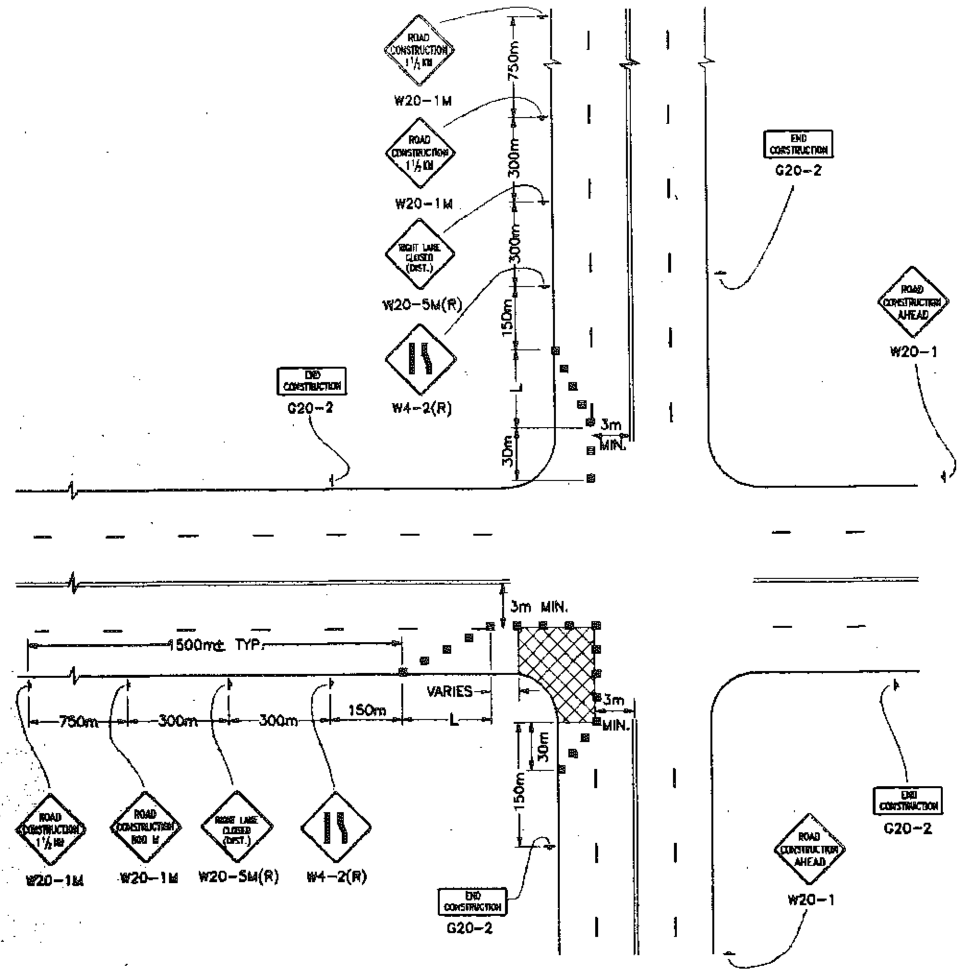


CASE XVII
TYPICAL APPLICATION
LANE CLOSURE, 2-LANE HIGHWAY, AT CURVE

LEGEND

- CHANNELIZING DEVICE: FOR TYPE OF DEVICE TO BE USED, SEE THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES INCLUDED IN THE PLANS.
- TYPE 3 BARRICADE
- TYPE 1 OR 2 BARRICADE
- CONCRETE BARRIER (TEMPORARY)
- FLAGGER
- DIRECTION OF TRAVEL
- WORK AREA
- L TRANSITION TAPER LENGH:
  - L = MINIMUM LENGTH OF TAPER IN METERS
  - SPEED 45 MPH OR MORE: L = S x W
  - SPEED 40 MPH OR LESS: $L = \frac{WS^2}{60}$
  - S = NUMERICAL VALUE OF SPEED LIMIT OR 85 PERCENTILE SPEED
  - W = WIDTH OF OFFSET IN METERS
- ADVANCE WARNING FLASHING OR SEQUENCING ARROW PANEL
- D SEE WARNING SIGN PLACEMENT TABLE FOR DISTANCE (CONDITION A).
- CZ CLEAR ZONE (SEE GENERAL NOTE 16).
- ▲ THESE DEVICES ARE OPTIONAL. THEIR NEED SHALL BE DETERMINED BY DETOUR DESIGN AND/OR SCOPE OF CONSTRUCTION ACTIVITY, AND ARE REQUIRED WHEN THEY ARE INCLUDED IN THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES.
- FLASHING BEACON IS OPTIONAL – SIGN IS REQUIRED.
- VARIES BUFFER SPACE (SEE GENERAL NOTE 21).

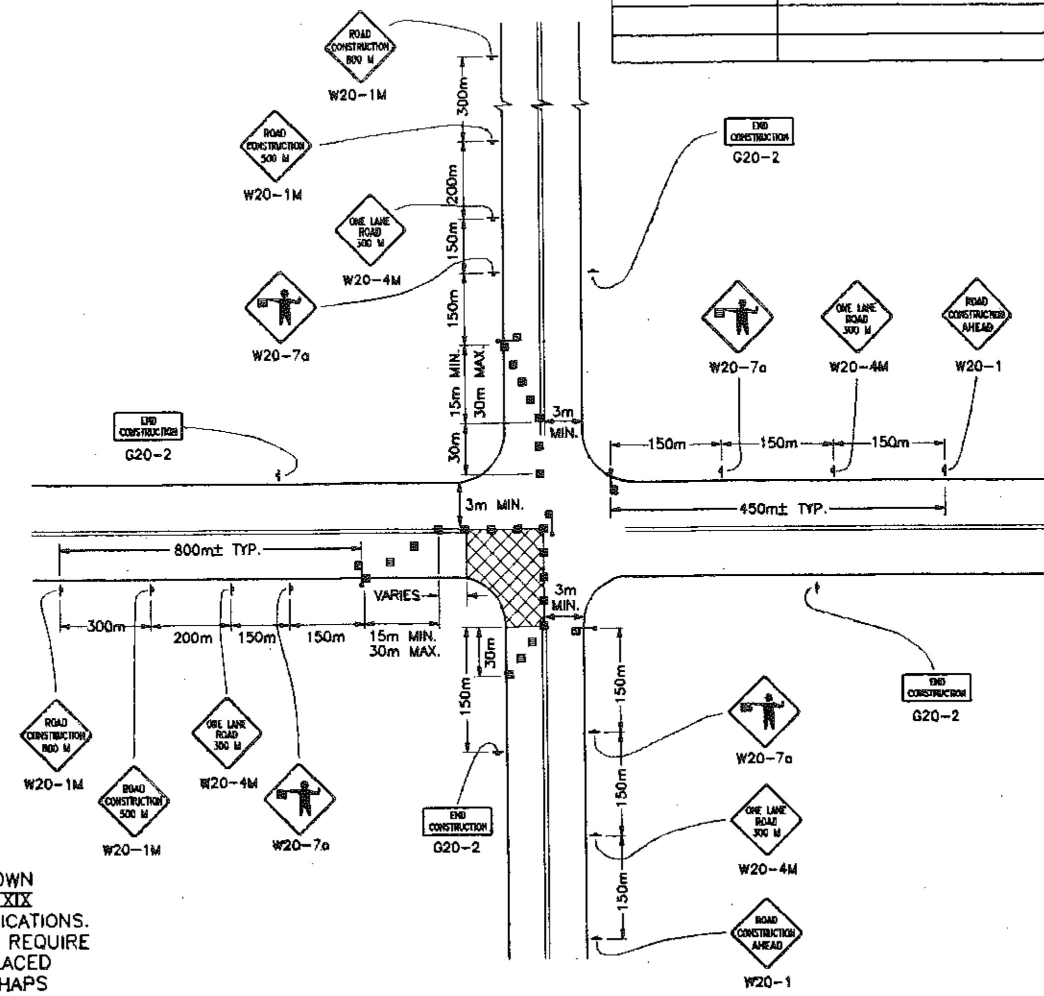
COLORADO DEPARTMENT OF TRANSPORTATION	
TRAFFIC CONTROLS FOR HIGHWAY CONSTRUCTION	
ISSUED BY STAFF TRAFFIC BRANCH	STANDARD PLAN NO. S-630-1
DATE REVISED / DATE:	SHEET 6 OF 9



CASE XVIII

TYPICAL APPLICATION
OF TRAFFIC CONTROL AROUND A WORK AREA
NEAR AN INTERSECTION, ONE LANE CLOSED

NOTE:
SIGN PLACEMENT SHOWN ON CASES XVIII AND XIX TYPIFIES RURAL APPLICATIONS. URBAN APPLICATIONS REQUIRE THE SIGNS TO BE PLACED WITHIN ONE, OR PERHAPS TWO, BLOCKS.

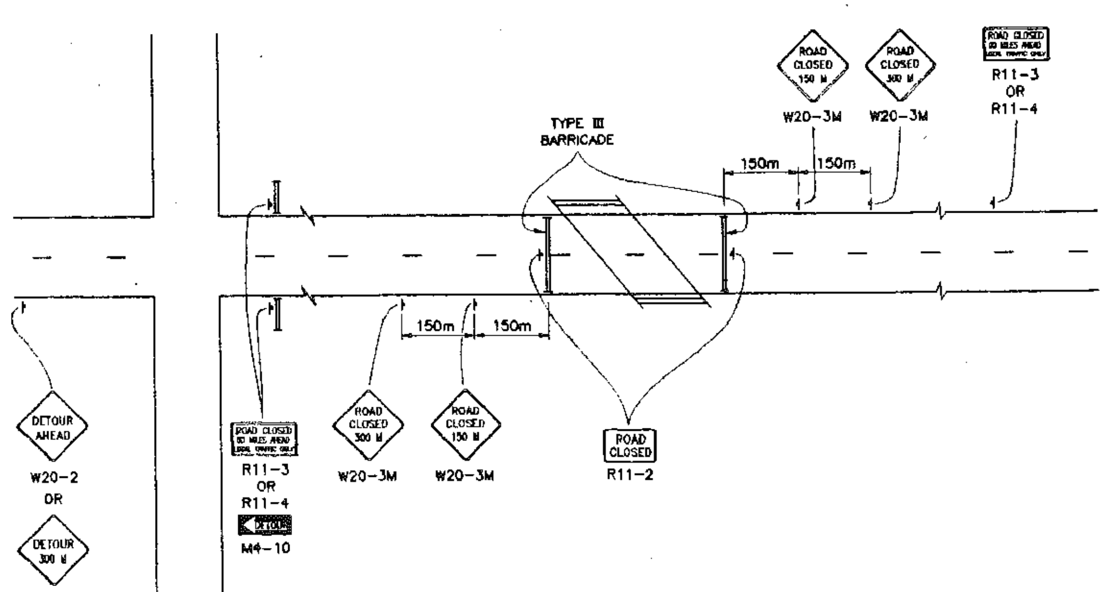


CASE XIX

TYPICAL APPLICATION
OF TRAFFIC CONTROL AROUND A WORK AREA
NEAR AN INTERSECTION

LEGEND

- ▪ CHANNELIZING DEVICE: FOR TYPE OF DEVICE TO BE USED, SEE THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES INCLUDED IN THE PLANS.
- TYPE 3 BARRICADE
- TYPE 1 OR 2 BARRICADE
- CONCRETE BARRIER (TEMPORARY)
- FLAGGER
- DIRECTION OF TRAVEL
- WORK AREA
- L TRANSITION TAPER LENGH:
  - L = MINIMUM LENGTH OF TAPER IN METERS
  - SPEED 45 MPH OR MORE: $L = S \times W$
  - SPEED 40 MPH OR LESS: $L = \frac{WS^2}{60}$
  - S = NUMERICAL VALUE OF SPEED LIMIT OR 85 PERCENTILE SPEED
  - W = WIDTH OF OFFSET IN METERS
- ADVANCE WARNING FLASHING OR SEQUENCING ARROW PANEL
- D SEE WARNING SIGN PLACEMENT TABLE FOR DISTANCE (CONDITION A).
- CZ CLEAR ZONE (SEE GENERAL NOTE 16).
- ▲ THESE DEVICES ARE OPTIONAL. THEIR NEED SHALL BE DETERMINED BY DETOUR DESIGN AND/OR SCOPE OF CONSTRUCTION ACTIVITY, AND ARE REQUIRED WHEN THEY ARE INCLUDED IN THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES.
- FLASHING BEACON IS OPTIONAL – SIGN IS REQUIRED.
- VARIES BUFFER SPACE (SEE GENERAL NOTE 21).



CASE XX

TYPICAL SIGNING
FOR ROAD CLOSURE

COLORADO DEPARTMENT OF TRANSPORTATION	
TRAFFIC CONTROLS FOR HIGHWAY CONSTRUCTION	
ISSUED BY STAFF TRAFFIC BRANCH	STANDARD PLAN NO. S-630-1
DATE:	SHEET 7 OF 9

DATE REVISED

REVISIONS	S-630-1	8/9

GENERAL NOTES

1. ALL CONSTRUCTION ZONE TRAFFIC CONTROL DEVICES, INCLUDING BUT NOT LIMITED TO BARRICADES, SIGNS, ARROW PANELS, FLASHING BEACON (PORTABLE), AND CHANNELIZING DEVICES, SHALL BE FURNISHED, INSTALLED, MAINTAINED (INCLUDING WASHING), REPLACED IF DAMAGED, REMOVED WHEN TEMPORARILY NOT IN USE AND RETURNED WHEN REQUIRED, RESET AS NECESSARY DURING THE PROGRESS OF CONSTRUCTION, AND REMOVED ENTIRELY WHEN THE PROJECT IS COMPLETED.

2. WORK ON THE PROJECT SHALL NOT BE STARTED UNTIL ALL REQUIRED TRAFFIC CONTROL DEVICES ARE IN PLACE, AND APPROVED BY THE ENGINEER.

3. WHEN SPEED LIMIT REDUCTION IS REQUIRED, SUCH REDUCTION SHALL BE IN ACCORDANCE WITH "AUTHORIZATION AND DECLARATION OF TEMPORARY SPEED LIMITS."

   WHEN A CHANGE IN AN EXISTING SPEED LIMIT IS REQUIRED, THE R2-1 SIGNS, SHOWN ON THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES, SHOULD BE INSTALLED AT THE LOCATIONS SHOWN ON THE TYPICAL CASES BY R2-1 (OPTIONAL) SIGNS.

   AN ADVISORY SPEED PLATE (W13-1) MAY BE USED WITH A WARNING SIGN WHEN THE MAXIMUM RECOMMENDED SPEED FOR CONDITION NAMED IS LOWER THAN THE POSTED SPEED LIMIT.

   THE REGULATORY OR ADVISORY SPEED REDUCTION DISPLAYED SHALL NOT EXCEED 25 km/h PER SIGN INSTALLATION.

4. ANY TRAFFIC CONTROL DEVICE THAT IS DAMAGED, WEATHERED, WORN, OR OTHERWISE DEEMED UNACCEPTABLE BY THE ENGINEER, SHALL BE REPLACED.

5. CONTRACTOR AND PERSONAL VEHICLE PARKING IS PROHIBITED WITHIN THE RIGHT-OF-WAY UNLESS DESIGNATED ON THE PLANS, OR APPROVED BY THE ENGINEER.

6. CONSTRUCTION TRAFFIC SIGNS SHALL BE MEASURED BY THE FOLLOWING SIZES AND DESCRIPTIONS:

PANEL SIZE A	0.001 TO 0.836 m^2 (INCLUDING TYPE 1 AND TYPE 2 BARRICADES).
PANEL SIZE B	0.837 TO 1.486 m^2
PANEL SIZE C	1.487 m^2 AND OVER.

   CONSTRUCTION TRAFFIC SIGN (SPECIAL), m^2, MAY BE USED FOR SOME PROJECT SPECIFIC INFORMATION SIGNS.

   FOR DETAILED DIMENSIONS OF SIGNS WITH SIGN CODE NUMBERS, SEE "STANDARD HIGHWAY SIGNS" AND THE "COLORADO SUPPLEMENT" THERETO. SIGN LAYOUTS FOR OTHER SIGNS WILL BE FURNISHED IN THE PLANS, TRANSMITTED TO THE ENGINEER AFTER AWARD, OR MAY BE AVAILABLE UPON REQUEST.

   W20-5 WARNING SIGNS SHALL BE FURNISHED WITH EXCHANGEABLE PLAQUES READING "RIGHT", "LEFT", "CENTER", "RIGHT 2", ETC. AT NO ADDITIONAL COST

7. ALL WARNING AND REGULATORY SIGNS SHALL BE POSTED ON BOTH SIDES OF THE ROADWAY ON DIVIDED HIGHWAYS, MULTI-LANE RAMPS, ONE-WAY STREETS, AND AS DIRECTED BY THE ENGINEER.

8. ADDITIONAL TRAFFIC CONTROL DEVICES ADDRESSING FLAGGING, SPEED REDUCTION, ETC. WILL BE NECESSARY FOR SET-UP AND TAKE-DOWN OF MOST CASE APPLICATIONS; DAILY WORK SITE ACCESS; AND PAVEMENT MARKING REMOVAL AND INSTALLATION OPERATIONS.

9. BASED ON SIGHT DISTANCE AND OTHER CONSIDERATIONS, THE FINAL LOCATIONS OF SIGNS ARE SUBJECT TO APPROVAL OF THE ENGINEER.

10. IF CONSTRUCTION RELATED TRAFFIC CONGESTION BACKS UP BEYOND THE INSTALLED ADVANCE SIGN SEQUENCE, ADDITIONAL ADVANCE SIGNING SHALL BE PLACED BEYOND THE CONGESTION.

11. ALL SIGN MATERIAL SHALL BE SOUND AND DURABLE TO THE DEGREE NECESSARY FOR MAINTAINING EFFECTIVE AND NEAT APPEARING TRAFFIC CONTROLS, AND:

    a. SIGN PANELS MAY BE FABRICATED FROM PLYWOOD, STEEL, ALUMINUM, OR OTHER SUITABLE MATERIAL.
    b. REFLECTIVE SHEETING SHALL CONFORM TO ASTM D4956. THE TYPE SHALL BE AS DESCRIBED IN THE STANDARD SPECIFICATIONS AND/OR AS SHOWN ON THE PLANS.
    c. SYMBOLS AND LEGEND SHALL BE OF GOOD WORKMANSHIP (UNEVEN LETTERING WILL NOT BE ACCEPTED).
    d. PORTABLE OR TEMPORARY MOUNTING SHALL NOT BE CONSTRUCTED OR WEIGHTED BY ANY METHOD OR MATERIAL THAT MAKES THEM HAZARDOUS TO TRAFFIC.
    e. CERTAIN POST SIZES AND SHAPES REQUIRE A "BREAK-AWAY" DEVICE. SEE THE APPLICABLE STANDARD PLAN. OTHER POST DESIGNS OR SYSTEMS REQUIRE THE SUBMITTAL OF AN FHWA LETTER OF ACCEPTANCE TO THE ENGINEER PRIOR TO USE.

12. ALL CONSTRUCTION SIGN PLACEMENT SHALL BE IN ACCORDANCE WITH STANDARD PLAN "TYPICAL GROUND SIGN PLACEMENT" UNLESS OTHERWISE APPROVED.

    SIGNS APPROVED TO BE MOUNTED ON PORTABLE SUPPORTS, OR APPROPRIATE SIGNS MOUNTED ON BARRICADES, MAY BE AT LOWER HEIGHTS, BUT THE BOTTOM OF THE SIGNS SHALL NOT BE LESS THAN 300 mm ABOVE THE PAVEMENT ELEVATION.

13. SIGNS MOUNTED IN THE MEDIAN OF DIVIDED HIGHWAYS, WHERE MEDIAN BARRIER IS IN PLACE, SHALL NOT USE "STRADDLE" TYPE SUPPORTS. THEY MUST BE MOUNTED ON THE BARRIER WITH A "SADDLE" TYPE BRACKET. IF THE BRACKET ALLOWS THE SIGN PANEL TO BE TURNED PARALLEL TO THE ROADWAY, THE SIGN MAY BE TURNED AND REMAIN IN PLACE WHEN NOT APPLICABLE. LAYING THE SIGN PANEL DOWN IN A HORIZONTAL POSITION IS NOT PERMITTED. ALL OTHER SIGNS THAT ARE NOT IN USE SHALL BE REMOVED BEYOND THE CLEAR ZONE AND NOT BE VISIBLE TO TRAFFIC. ALL STORAGE AREAS SHALL BE APPROVED.

14. TRAFFIC CONES SHALL BE AT LEAST 700 mm IN HEIGHT. HOWEVER, THE MINIMUM SIZE SHALL BE 900 mm WHEN THEY ARE USED ON FREEWAYS AND EXPRESSWAYS, OR DURING NIGHT TIME WORKING HOURS. THEY SHOULD ALSO BE 900 mm WHEN USED ON OTHER HIGH SPEED ROADWAYS (75 km/h OR MORE) WITH AN ADT OF 6,000 OR MORE.

15. TYPE 1 BARRICADES AND VERTICAL PANELS SHALL NOT BE USED ON FREEWAYS, EXPRESSWAYS, OR OTHER HIGH SPEED ROADWAYS (75 km/h OR MORE).

16. WHEN TWO-WAY TRAFFIC IS PLACED ON ONE ROADWAY OF A NORMALLY DIVIDED HIGHWAY, OPPOSING TRAFFIC SHALL BE SEPARATED EITHER WITH CONCRETE BARRIER (TEMPORARY), OR WITH CHANNELIZING DEVICES APPROVED FOR THIS APPLICATION, THROUGHOUT THE LENGTH OF TWO-WAY OPERATION. THE TRANSITION ZONES SHALL HAVE CONCRETE BARRIER (TEMPORARY).

    THE BARRIER SHALL BE TIED TO AN EXISTING STRUCTURE OR GUARD RAIL, FLARED OR EXTENDED TO MEET CLEAR ZONE REQUIREMENTS, OR FITTED WITH AN IMPACT ATTENUATION DEVICE.

    CONCRETE BARRIER INSTALLATIONS SHALL CONFORM TO THE REQUIREMENTS OF THE AASHTO ROADSIDE DESIGN GUIDE OF LATEST ISSUE (CLEAR ZONE, FLARE RATE, SLOPES, ETC.).

17. CHANNELIZING DEVICE SPACING, IN METERS, SHALL BE AS FOLLOWS:
    a. FOR TAPERS AND TRANSITIONS, SPACING EQUALS THE NUMERICAL VALUE OF THE SPEED LIMIT. (e.g. 75 km/h = 13.5 m)
    b. FOR TANGENTS ALONG THE BUFFER SPACE OR WORK AREA, SPACING MAY EQUAL TWO TIMES THE SPEED LIMIT. (e.g. 80 km/h = 15 m TO 30 m MAXIMUM)

18. FOR DETAILS ON BARRICADES, CONCRETE BARRIER (TEMPORARY), VERTICAL PANELS, AND FLASHING BEACON (PORTABLE), SEE THE APPLICABLE STANDARD PLANS.

19. FLOOD LIGHTS SHALL BE USED TO ILLUMINATE FLAGGER STATIONS DURING THE HOURS OF DARKNESS UNLESS OTHERWISE APPROVED. A TYPICAL LIGHT SHOULD PROVIDE THE FOLLOWING: A FULLY DIRECTIONAL SWIVEL MOUNT QUARTZ LIGHT SOURCE (500 WATT MINIMUM), SELF-SUPPORTING STAND WITH VARIABLE LIGHT HEIGHT FROM OF MINUMUM OF 2.4 m ABOVE THE ROADWAY, AND A POWER SOURCE. IT SHALL ILLUMINATE THE STATION AREA AND A FLAGGER ESCAPE PATH, BUT SHALL NOT PRESENT ANY GLARE TO TRAFFIC.

20. IF WORK ON THE ROADWAY IS FOR AN EXTENDED PERIOD, INAPPLICABLE PAVEMENT MARKINGS ARE TO BE REMOVED, AND FULL COMPLIANCE OR TEMPORARY PAVEMENT MARKINGS ARE TO BE INSTALLED IN ACCORDANCE WITH THE APPLICABLE SPECIFICATIONS, (PAVEMENT MARKING GENERAL), AND/OR AS DETAILED ON THE PLANS.

    FOR ADDITIONAL PAVEMENT MARKING DETAILS, SEE STANDARD PLAN "TYPICAL PAVEMENT MARKINGS".

21. BUFFER SPACE IS OPTIONAL. NEED MUST BE DETERMINED ON A PROJECT OR SITE SPECIFIC BASIS. WHEN A BUFFER SPACE IS USED, DIMENSIONS AND/OR DEVICES USED ARE TO BE INCORPORATED IN THE PROJECT TRAFFIC CONTROL PLAN (TCP) OR THE CONTRACTOR'S METHOD OF HANDLING TRAFFIC (MHT).

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	ISSUED BY STAFF TRAFFIC BRANCH	STANDARD PLAN NO.
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		SHEET 8 OF 9

TYPICAL CONSTRUCTION ZONE SIGNS

THESE SIGNING NOTES ARE INTENDED AS A QUICK REFERENCE FOR TYPICAL SIGN USE AND PLACEMENT IN CONSTRUCTION ZONES.

* PLACEMENT SHOULD BE IN ACCORDANCE WITH WARNING SIGN PLACEMENT TABLE.

G20-1 "ROAD/CONSTRUCTION/NEXT XX km" – THIS SIGN SHALL BE ERECTED AT THE LIMITS OF ANY ROAD CONSTRUCTION OR MAINTENANCE PROJECT OF MORE THAN 3.3 km IN LENGTH WHERE TRAFFIC IS MAINTAINED THROUGH THE PROJECT.

G20-2 "END/CONSTRUCTION" – THIS SIGN SHOULD BE ERECTED APPROXIMATELY 150 m BEYOND THE END OF THE PROJECT.

G20-4 "PILOT CAR/FOLOW ME" – THIS SIGN SHALL BE MOUNTED IN A CONSPICUOUS POSTITION ON THE REAR OF A VEHICLE USED FOR GUIDING ONE-WAY TRAFFIC THROUGH OR AROUND THE PROJECT.

M4-9( ) "DETOUR/<<<<<<" – THIS SIGN IS USED FOR UNNUMBERED ROUTES; FOR USE IN EMERGENCY SITUATIONS; FOR PERIODS OF SHORT DURATION; OR WHERE, OVER RELATIVELY SHORT DISTANCES, IT IS NOT NECESSARY TO SHOW ROUTE MARKERS TO GUIDE TRAFFIC ALONG THE DETOUR AND BACK TO ITS AUTHORIZED ROUTE.

M4-10( ) "DETOUR ARROW" – THIS SIGN SHOULD BE MOUNTED JUST BELOW THE ROAD CLOSED SIGN AT THE POINT WHERE THE DETOUR ROADWAY OR ROUTE HAS BEEN ESTABLISHED DUE TO THE CLOSURE OF THE STREET OR HIGHWAY TO THROUGH TRAFFIC.

R2-1( ) "SPEED/LIMIT/XX" – THESE SIGNS ARE INTENDED TO REDUCE TRAFFIC SPEED IN ADVANCE OF THE DAILY WORK AREA WITHIN THE OVERALL PROJECT LIMITS.

R2-1(90) "SPEED/LIMIT/90" – THIS SIGN IS INTENDED FOR USE 150 m PAST THE "END CONSTRUCTION" SIGN TO BRING TRAFFIC BACK TO ORIGINAL POSTED SPEED.

R11-2 "ROAD/CLOSED" – THIS SIGN IS TO BE MOUNTED ON THE BARRICADE THAT IS PLACED BEFORE THE WORK ZONE ENTRANCE TO PROHIBIT TRAFFIC FROM ENTERING THE WORK ZONE.

R11-3 "ROAD CLOSED/X km AHEAD/L.T.O. – THIS SIGN SHOULD BE PLACED WHERE THROUGH TRAFFIC MUST DETOUR TO AVOID THE CLOSURE OF THE ROAD SOME DISTANCE BEYOND, BUT WHERE THE ROAD IS OPEN TO LOCAL TRAFFIC UP TO THE POINT OF CLOSURE.

R11-4 "ROAD CLOSED/TO/THRU TRAFFIC" FOR URBAN USE – THIS SIGN SHOULD BE PLACED WHERE THROUGH TRAFFIC MUST DETOUR TO AVOID THE CLOSURE OF THE ROAD SOME DISTANCE BEYOND, BUT WHERE THE ROAD IS OPEN TO LOCAL TRAFFIC UP TO THE POINT OF CLOSURE.

W1-1( ) "TURN ARROW" – THIS SIGN IS INTENDED FOR USE WHERE ENGINEERING INVESTIGATIONS OF ROADWAY CONDITIONS SHOW THE RECOMMENDED SPEED ON THE TURN TO BE 50 km/h OR LESS.*

W1-2( ) "CURVE ARROW" – THIS SIGN IS INTENDED FOR USE WHERE ENGINEERING INVESTIGATIONS OF ROADWAY CONDITIONS SHOW THE RECOMMENDED SPEED ON THE CURVE TO BE IN THE RANGE BETWEEN 50 AND 100 km/h. *

W1-3( ) "REVERSE TURN ARROW" – THIS SIGN IS INTENDED FOR USE WHERE TWO TURNS OR THE CURVE AND A TURN IN OPPOSITE DIRECTIONS ARE SEPARATED BY A TANGENT OF LESS THAN 180 m.*

W1-4( ) "REVERSE CURVE ARROW" – THIS SIGN IS INTENDED FOR USE WHERE TWO CURVES IN OPPOSITE DIRECTIONS ARE SEPARATED BY A TANGENT OF LESS THAN 180 m.*

W3-2 "YIELD AHEAD" – THIS SIGN IS INTENDED FOR USE AT THE APPROACH TO THE YIELD SIGN THAT IS NOT VISIBLE FOR A SUFFICIENT DISTANCE TO PERMIT THE DRIVER TO BRING HIS VEHICLE TO A STOP AT THE YIELD SIGN. *

W4-2 "LEFT (RIGHT) LANE TRANSITION SYMBOL" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF THE REDUCTION IN THE NUMBER OF TRAFFIC LANES IN THE DIRECTION OF TRAVEL ON THE MULTILANE HIGHWAY. *

W5-1 "ROAD NARROWS" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF THE TRANSITION ON THE ROAD WHERE THE PAVEMENT WIDTH IS REDUCED ABRUPTLY TO A WIDTH SUCH THAT TWO CARS CANNOT PASS WITHOUT REDUCING SPEED. *

W5-2a "NARROW BRIDGE SYMBOL" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF A BRIDGE OR CULVERT HAVING A CLEAR TWO-WAY ROADWAY WIDTH OF 5 TO 5.5 m OR ANY BRIDGE OR CULVERT HAVING A ROADWAY CLEARANCE LESS THAN THE WIDTH OF THE APPROACH PAVEMENT.*

W5-3 "ONE LANE/BRIDGE" – THIS SIGN SHOULD BE PLACED ON TWO-WAY ROADWAYS IN ADVANCE OF THE BRIDGES OR CULVERTS WHERE THE ROADWAY WIDTH IS LESS THAN 5 m (5.5 m FOR COMMERCIAL VEHICLES) OR WHEN THE ALIGNMENT IS POOR ON THE APPROACH TO THE STRUCTURE HAVING A CLEAR ROADWAY WIDTH OF 5.5 m OR LESS. *

W6-1 "DIVIDED HIGHWAY SYMBOL" – THIS SIGN SHOULD BE PLACED ON THE APPROACHES TO THE SECTION OF HIGHWAY WHERE OPPOSING FLOWS OF TRAFFIC ARE SEPARATED BY A PHYSICAL MEDIAN.

W6-2 "DIVIDED HIGHWAY ENDS SYMBOL" – THIS SIGN SHOULD BE PLACED AT THE END OF THE SECTION OF PHYSICALLY DIVIDED HIGHWAY AS A WARNING OF TWO-WAY TRAFFIC AHEAD.

W6-3 "TWO-WAY TRAFFIC SYMBOL" – THIS SIGN IS INTENDED FOR USE TO GIVE WARNING OF TRANSITION FROM A SEPARATED ONE-WAY ROADWAY TO A TWO-WAY ROADWAY. *

W7-1 "HILL SYMBOL" – THIS SIGN SHOULD BE PLACED AT A POINT IN ADVANCE OF THE DOWNGRADE WHERE THE LENGTH, PERCENT OF GRADE, HORIZONTAL CURVATURE, OR OTHER PHYSICAL FEATURES REQUIRE SPECIAL CONSIDERATION ON THE PART OF DRIVERS. *

W8-1,W8-2 "BUMP"/"DIP" – THESE SIGNS ARE INTENDED FOR USE TO GIVE WARNING OF A SHARP RISE OR DEPRESSION IN THE PROFILE OF THE ROAD THAT IS SUFFICIENTLY ABRUPT TO AFFECT VEHICLE OPERATION OR CAUSE CONSIDERABLE DISCOMFORT TO PASSENGERS. *

W8-3a "PAVEMENT ENDS SYMBOL" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF A POINT WHERE THE PAVEMENT SURFACE CHANGES FROM A HARD-SURFACED PAVEMENT TO THE LOW-TYPE SURFACE OR EARTH ROAD. *

W8-4 "SOFT SHOULDER" – THIS SIGN IS INTENDED FOR USE TO WARN OF A SOFT SHOULDER CONDITION THAT COULD PRESENT A PROBLEM TO VEHICLES THAT MAY GET OFF THE PAVEMENT. *

W8-5 "SLIPPERY WHEN WET SYMBOL" – THIS SIGN SHOULD BE PLACED IN ADVANCE OF THE CONDITION WHERE THE HIGHWAY SURFACE IS SLIPPERY BEYOND WHAT IS ORDINARY WHEN WET. *

W9-1( ) "LEFT (RIGHT) LANE ENDS" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF THE PAVEMENT WIDTH TRANSITION SIGN (W4-2).

W9-2( ) "LANE ENDS/MERGE LEFT (RIGHT)" – THIS SIGN IS INTENDED FOR USE AS A SUPPLEMENT TO THE PAVEMENT WIDTH TRANSITION SIGN (W4-2).

W12-1 "DOUBLE ARROW SYMBOL" – THIS SIGN SHOULD BE PLACED AT THE POINT OF THE OBSTRUCTION IN THE ROADWAY, WHERE TRAFFIC IS PERMITTED TO PASS ON EITHER SIDE OF THE OBSTRUCTION.

W12-2 "LOW CLEARANCE SYMBOL" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF AN OBSTRUCTION TO WARN VEHICLE OPERATORS OF CLEARANCES LESS THAN THE MAXIMUM VEHICLE HEIGHT PERMITTED PLUS 300 mm. *

W13-1( ) "ADVISORY SPEED PLAQUE" – THIS SIGN IS INTENDED TO SUPPLEMENT WARNING SIGNS ONLY AND SHALL NOT BE MOUNTED ALONE. IT IS USED TO INDICATE THE MAXIMUM RECOMMENDED SPEED FOR THE INDICATED CONDITION.

W20-1 "ROAD/CONSTRUCTION/(DIST.)" – THIS SIGN IS TO BE LOCATED IN ADVANCE OF THE INITIAL ACTIVITY OR DETOUR A DRIVER MAY ENCOUNTER, AND IS INTENDED TO BE USED AS A WARNING OF OBSTRUCTIONS OR RESTRICTIONS.

W20-2 "DETOUR/(DIST.)" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF THE POINT AT WHICH TRAFFIC IS DIVERTED OVER A TEMPORARY ROADWAY OR ROUTE.

W20-3 "ROAD/CLOSED/(DIST.)" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF A POINT AT WHICH A ROADWAY IS CLOSED TO ALL TRAFFIC OR TO ALL BUT LOCAL TRAFFIC.

W20-4 "ONE LANE/ROAD/(DIST.)" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF A POINT WHERE TRAFFIC IN BOTH DIRECTIONS MUST USE A SINGLE LANE.

W20-5( ) "XXX LANE/CLOSED/(DIST.)" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF A POINT WHERE ONE LANE OF A MULTIPLE-LANE ROADWAY IS CLOSED. IT SHOULD BE PROVIDED WITH INTERCHANGEABLE PLAQUES READING "RIGHT", "LEFT", AND "CENTER" AT NO ADDITIONAL COST TO THE PROJECT.

W20-7a "FLAGGER SYMBOL" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF ANY POINT AT WHICH A FLAGGER HAS BEEN STATIONED TO CONTROL TRAFFIC THROUGH OR AROUND THE PROJECT. *

W20-52 "GROOVED/PAVEMENT/AHEAD" – THIS SIGN IS INTENDED TO BE USED IN ADVANCE OF A ROADWAY THAT HAS BEEN GROOVED AND/OR ROTO MILLED.

W21-1a "WORKER SYMBOL" – THIS SIGN IS INTENDED FOR USE IN CONJUNCTION WITH MINOR MAINTENANCE AND PUBLIC UTILITY OPERATIONS FOR THE PROTECTION OF MEN WORKING IN OR NEAR THE ROADWAY*

W21-2 "FRESH/OIL" – THIS SIGN IS INTENDED FOR USE WHERE RE-SURFACING OPERATIONS HAVE RENDERED THE SURFACE OF THE PAVEMENT TEMPORARILY WET, AND OBJECTIONABLE SPLASHING ON VEHICLES MAY OCCUR. *

W21-3 "ROAD/MACHINERY/AHEAD" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF THE AREAS WHERE HEAVY EQUIPMENT IS OPERATING IN OR ADJACENT TO THE ROADWAY.*

W21-4 "ROAD/WORK/(DIST.)" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF MAINTENANCE OR MINOR RECONSTRUCTION OPERATIONS IN THE ROADWAY.

W21-5 "SHOULDER/WORK" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF THE PROJECT INVOLVING THE SHOULDER, WHERE THE TRAVELED WAY REMAINS UNOBSTRUCTED.

W21-6 "SURVEY/CREW" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF A POINT WHERE A SURVEYING CREW IS WORKING IN OR ADJACENT TO THE ROADWAY.*

W21-13a "SHOULDER/DROP OFF" – THIS SIGN IS INTENDED FOR USE AS AN EDUCATIONAL PLAQUE IN CONJUNCTION WITH A SHOULDER DROP OFF SIGN.

W21-13( ) "SHOULDER DROP OFF SYMBOL" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF A SHOULDER DROP-OFF THAT EXCEEDS 75 mm IN HEIGHT. *

W21-14a "UNEVEN/LANES" – THIS SIGN IS INTENDED FOR USE AS AN EDUCATIONAL PLAQUE IN CONJUNCTION WITH THE UNEVEN LANE SIGN.

W21-14( ) "UNEVEN LANES SYMBOL" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF AN UNEVEN ADJACENT LANE SITUATION THAT EXCEEDS 25 mm IN HEIGHT. *

W22-1 "BLASTING/ZONE/(DIST.)" – THIS SIGN IS INTENDED FOR USE IN ADVANCE OF ANY POINT OR WORK SITE WHERE THERE ARE EXPLOSIVES BEING USED. THE W22-2 AND W22-3 SIGNS MUST BE USED IN SEQUENCE WITH THIS SIGN.

W22-2 "TURN OFF/2-WAY/RADIO" – THIS SIGN IS TO BE USED IN SEQUENCE WITH THE W22-1 AND W22-3 SIGNS AND PLACED AT LEAST 300 m FROM THE BEGINNING OF THE BLASTING ZONE.

W22-3 "END/BLASTING/ZONE" – THIS SIGN IS TO BE USED TO DENOTE THE END OF THE RADIO INFLUENCE AREA AND SHALL BE PLACED A MINIMUM OF 300 m FROM THE BLASTING ZONE, EITHER WITH OR PRECEDING THE END CONSTRUCTION SIGN.

WARNING SIGN PLACEMENT TABLE (1)

Posted or 85 percentile speed km/h	Condition A --high judgement	General warning signs (3)					
		Condition B --Stop condition	Condition C --Declaration to listed advisory speed – km/h				
		0	20	30	50	60	80
30	53	(4)	(4)				
40	75	(4)	30 (2)				
50	98	30	45	30			
60	120	45	60	53			
70	165	90	105	90	75		
80	188	113	128	120	98	68	
90	210	135	150	143	120	90	
100	255	195	195	188	173	150	113

TYPICAL SIGNS FOR THE LISTED CONDITIONS IN TABLE II-1;
CONDITION A--MERGE, RIGHT LANE ENDS, ETC.;
CONDITION B--CROSS ROAD, STOP AHEAD, SIGNAL AHEAD, PED-XING, ETC.;
CONDITION C--TURN, CURVE, DIVIDED ROAD, HILL, DIP, ETC.

(1) DISTANCES SHOWN ARE FOR LEVEL ROADWAYS. CORRECTIONS SHOULD BE MADE FOR GRADES. IF 1200 mm SIGNS ARE USED, THE LEGIBILITY DISTANCE MAY BE INCREASED TO 60 m. THIS WOULD ALLOW REDUCING THE ABOVE DISTANCE BY 23 m.

(2) IN URBAN AREAS, A SUPPLEMENTARY PLATE UNDERNEATH THE WARNING SIGN SHOULD BE USED SPECIFYING THE DISTANCE TO THE CONDITION IF THERE IS AN IN-BETWEEN INTERSECTION WHICH MIGHT CONFUSE THE MOTORIST.

(3) DISTANCE PROVIDES FOR 1-SECOND PIEV, 38 m SIGN LEGIBILITY DISTANCE, BRAKING DISTANCE FOR CONDITION B AND COMFORTABLE BREAKING DISTANCE FOR CONDITION C AS INDICATED IN "A POLICY ON GEOMETRIC DESIGN OF HIGHWAYS AND STREETS," 1984, AASHTO, FIGURE 11-13. (PIEV = PERCEPTION, IDENTIFICATION/UNDERSTANDING, EMOTION/DECISION MAKING, AND VOLITION/EXECUTION OF DECISION).

(4) NO SUGGESTED MINIMUM DISTANCE PROVIDED. AT THESE SPEEDS, SIGN LOCATION DEPENDS ON PHYSICAL CONDITIONS AT SITE.

NOTE:
WHEN CALLED FOR IN THE PLANS, PUBLIC RELATIONS/SAFETY SIGNS SUCH AS W20-51a "Give 'em a Brake", MAY BE PLACED IN THE ADVANCE SIGNING SEQUENCE WHERE THEY DO NOT INTERFERE WITH REQUIRED TRAFFIC CONTROL SIGNING.

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S-630-1