without any conduit. A significant portion of outside plant investment consists of the poles, trenches, conduits, and other structure that support or house the copper and fiber cables. In some cases, electric utilities, cable companies, and other telecommunications providers share structure with the LEC and, therefore, only a portion of the costs associated with that structure are borne by the LEC. Outside plant investment also includes the cost of the SAIs and DLCs that connect the feeder and distribution plant.

B. Engineering Assumptions and Optimizing Routines

66. As noted in the *Inputs Further Notice*, the model determines outside plant investment based on certain cost minimization and engineering considerations that have associated input values.[164] In the *Inputs Further Notice*, we recognized that it was necessary to examine certain input values related to the engineering assumptions and optimization routines in the model that affect outside plant costs.[165] Specifically, we tentatively concluded that: (1) the optimization routine in the model should be fully activated; (2) the model should not use T-1 feeder technology; and (3) the model should use rectilinear distances and a "road factor" of one.[166]

1. Optimization

67. When running the model, the user has the option of optimizing distribution plant routing via a minimum spanning tree algorithm discussed in the model documentation.[167] The algorithm functions by first calculating distribution routing using an engineering rule of thumb and then comparing the cost with the spanning tree result, choosing the routing that minimizes annualized cost.[168] The user has the option of not using the distribution optimization feature, thereby saving a significant amount of computation time, but reporting network costs that may be significantly higher than with the optimization. The user also has the option of using the optimization feature only in the lowest density zones.

68. In reaching our tentative conclusion that the model should be run with the optimization routine fully activated in all density zones, we recognized that using full

[164] *See Inputs Further Notice* at paras. 56-63.

[165] *Inputs Further Notice* at para. 56.

[166] *Inputs Further Notice* at paras. 58, 61-62.

[167] The model uses a minimum spanning tree algorithm based on the Prim algorithm. The model always optimizes feeder plant. *See* HCPM Dec. 15, 1998 documentation at 13.

[168] HCPM Dec. 15, 1998 documentation at 11.

optimization can substantially increase the model's run time.[169] We noted that a preliminary analysis of comparison runs with full optimization versus runs with no optimization indicated that, for clusters with line density greater than 500, the rule of thumb algorithm results in the same or lower cost for nearly all clusters.[170] Accordingly, we sought comment on whether an acceptable compromise to full optimization would be to set the optimization factor at "-p500," as described in the model documentation.[171]

69. We adopt our tentative conclusion that the model should be run with the optimization routine fully activated in all density zones when the model is used to calculate the forward-looking cost of providing the services supported by the federal mechanism. The first of the ten criteria pronounced by the Commission to ensure consistency in calculations of federal universal support specifies that "[t]he technology assumed in the cost study or model must be the least-cost, most efficient, and reasonable technology for providing the supported services that is currently being deployed."[172] As we explained in the *Inputs Further Notice*, running the model with the optimization routine fully activated complies with this requirement.[173] In contrast, running the model with the optimization routine disabled may result in costs that are significantly higher than with full optimization. The majority of commenters that address the optimization issue support the use of full optimization.[174] GTE opposes any implementation of optimization.[175]

70. We agree with AT&T and MCI and GTE that it is inappropriate to deviate

[169] *Inputs Further Notice* at para. 58.

[170] *See Inputs Further Notice* at para. 58 n. 135. Since, under full optimization, the model chooses the least cost of the full optimization algorithm or the rule of thumb algorithm, a comparison run as described above can show how well the full optimization performs as a function of density.

[171] *See* HCPM Dec. 15, 1998 documentation at 30-31; *see also* Design History of HCPM, April 6, 1999 at http://www.fcc.gov/ccb/apd/hcpm.

[172] *Universal Service Order,* 12 FCC Rcd at 8913, para. 250.

[173] *Inputs Further Notice* at para. 58.

[174] *See e.g.*, AT&T and MCI *Inputs Further Notice* comments at 9-10; US West *Inputs Further Notice* comments at 21; SBC *Inputs Further Notice* comments at 7. We note that SBC supports full optimization so long as its application produces a significant difference in the results. As we explain, application of full optimization does produce a significant difference in the results. Moreover, SBC states that the optimization routine offers "the most cost effective design." *Id.*

[175] GTE *Inputs Further Notice* comments at 33-35; GTE *Inputs Further Notice* reply comments at 9-11.

from full optimization merely to minimize computer run time.[176] While the rule of thumb algorithm generally results in costs that are approximately the same as the spanning tree algorithm for dense clusters, for some dense clusters the spanning tree algorithm will result in lower costs. For this reason, we believe that any choice in maximum density clusters in which the minimum spanning tree algorithm is not applied may result in an arbitrary overestimate of costs for some clusters. Accordingly, running the model with full optimization is consistent with ensuring that the model uses the least-cost, most efficient, and reasonable distribution plant routings for providing the supported services.

71. As explained above, the model seeks to minimize costs by selecting the lower of the cost estimates from the spanning tree algorithm and the rule of thumb algorithm. Both GTE and US West challenge the selection of the routing that minimizes annualized cost on the basis of a comparison between an engineering rule of thumb and the spanning tree result.[177] US West claims that use of the rule of thumb approach is inappropriate because combining it with the spanning tree analytical approach to determine the amount of needed plant biases the results downward and will produce inappropriately low results.[178]

72. We find that US West's concerns are misplaced. Contrary to US West's characterization, the rule of thumb used in the model is not an averaging methodology.[179] Instead, it is a methodology that determines a sufficient amount of investment to serve each customer in every cluster using a standardized approach to network design. This approach connects every populated microgrid cell to the SAI using routes which are placed along the vertical and horizontal boundaries of the microgrid cells constructed in the distribution algorithm.[180] The rule-of-thumb algorithm is somewhat similar in its functioning to the so-

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[176] AT&T and MCI *Inputs Further Notice* comments at 10; GTE *Inputs Further Notice* comments at 33. We note that although GTE opposes any implementation of optimization, GTE also specifically addressed whether the compromise to full optimization on which we sought comment was acceptable.

[177] US West *Inputs Further Notice* comments at 18-21; GTE *Inputs Further Notice* comments at 34-35.

[178] US West contends that, because the optimization algorithm functions by choosing between the lowest value produced by the rule of thumb or the spanning tree, the optimization algorithm retains those instances where the rule of thumb underestimates the amount of plant needed while eliminating all estimates that exceed the more analytically derived results, thereby biasing the results downward. In order to remedy this flaw, US West recommends that the model be modified to consider only the minimum spanning tree results for distribution design.

[179] *See* US West *Inputs Further Notice* comments at 18-21.

[180] Because the optimization routine allows for the possibility of some, but not all possible junction nodes (also called Steiner nodes), it is possible that the "rule of thumb" can provide a feasible lower cost result than the optimization routine in certain cases. As explained in the model documentation, junction nodes can sometimes reduce the cost of constructing a communications network. HCPM Dec.15, 1998 documentation at 14.

called "pinetree" methodology proposed by both the early HAI and BCPM models for building feeder plant. Thus, the rule of thumb provides an independent calculation of sufficient outside plant for each cluster. The minimum spanning tree algorithm connects drop terminal points to the SAI using a more sophisticated algorithm in which routes are not restricted to following the vertical and horizontal boundaries of microgrid cells. The algorithm "chooses" a path independently of the set route structure defined by the rule-of-thumb,but still connects all drop terminals to the SAI. Since both the rule of thumb algorithm and the spanning tree algorithm use currently available technologies and generate investments that are sufficient to provide supported services, an approach which selects the minimum cost based on an evaluation of both of the algorithms is fully consistent with cost minimization principles.[181]

73. We also disagree with GTE's assertion that the optimization routine should be disabled because it disproportionately affects lower density areas where universal service is needed most.[182] The task of the model is to estimate the cost of the least-cost, most-efficient network that is sufficient to provide the supported services. Moreover, we note that the model does not determine the level of high-cost support amounts. We have taken steps in our companion order to ensure that sufficient support is provided for rural and high-cost areas.

74. We also reject GTE's claim that the optimization routine does not work as intended.[183] GTE bases this contention on the observation that in some instances when the optimization factor is increased from -p100 to -p200 (i.e. going from density zones less than or equal to 100 lines per square mile to density zones less than or equal to 200 lines per square mile), both loop investment and universal service requirements increase. This,

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[181] US West's recommendation that only the minimum spanning tree results be recognized would have us ignore accepted practices in cost minimization. Because it is not possible in the general case to solve for the optimal solution, it is accepted practice in cost minimization analysis to examine the results of various available alternative cost minimization methodologies and choose the lowest cost result, provided that each alternative meets the appropriate design standards. This is the same principle on which Branch and Bond algorithms work. *See e.g.,* Mark S. Daskin, *Network and Discrete Location: Models, Algorithms, and Applications* (1995). In so doing, the result that is chosen is the result that is closer to the least cost, while providing a sufficient amount of plant to provide the supported services. For these reasons, the optimization algorithm employed in the model produces results superior to those produced by the application of only a single cost minimization methodology.

[182] GTE asserts that an analysis of GTE's service area in Oregon reveals that a majority of the cost impact occurs when the spanning tree algorithm optimizes clusters with less than 100 lines per square mile. GTE *Inputs Further Notice* reply comments at 11.

[183] GTE *Inputs Further Notice* reply comments at 11.

according to GTE, would not happen if the optimization worked properly.[184]

75. We disagree. Optimizing the distribution plant is not synonymous with optimizing the entire network. Because the model's optimization routine optimizes distribution and feeder sequentially, and the starting point for the optimization of feeder plant is the distribution plant routing chosen, there are occasions when the optimal feeder plant will be more costly than it would be if distribution plant and feeder plant had been optimized simultaneously. In some cases, the lower distribution investment produced by the optimization routine may be offset by higher feeder investment, resulting in higher total outside plant costs than produced by the rule of thumb algorithm.[185] Contrary to GTE's assertion, this phenomenon does not demonstrate that the optimization works improperly. To the contrary, it demonstrates that optimization occurs properly within the constraints of the model's design.

76. Moreover, we conclude that such rare occurrences do not outweigh the benefits of the optimization routine. The magnitude of the difference between the network cost produced by the optimization routine in these instances and the rule of thumb algorithm is *de minimis*. Furthermore, altering the model to optimize distribution investment and feeder investment simultaneously would greatly add to the complexity of the model.

2. T-1 Technology

77. A user of the model also has the option of using T-1 on copper technology as an alternative to analog copper feeder or fiber feeder in certain circumstances.[186] T-1 is a technology that allows digital signals to be transmitted on two pairs of copper wires at 1.544 Megabits per second (Mbps). If the T-1 option is enabled, the optimizing routines in the model will choose the least cost feeder technology among three options: analog copper; T-1 on copper; and fiber.[187] For serving clusters with loop distances below the maximum copper

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[184] GTE also claims that there are numerous cases where the optimization routine has resulted in increased costs at the wire center level. GTE *Input Further Notice* comments at 34-35. Specifically, GTE contends that when the optimization logic is applied to clusters with fewer than 100 lines per square mile for GTE's Florida serving area, total monthly costs for eight wire centers were higher than without optimization.

[185] This situation can occur because the minimum spanning tree algorithm may increase the distance of some customers in a cluster from the serving area interface in order to achieve lower overall costs through more efficient routing. In some cases, this increased distance might cause a cluster that fell within the maximum copper distance constraint under the rule of thumb algorithm to exceed that constraint. The increased cost of serving the cluster with the fiber feeder system could then increase total cost even though the optimization worked as intended in the distribution portion of the model.

[186] *See Inputs Further Notice* at para. 59.

[187] HCPM Dec. 15, 1998 documentation at 10.

loop length, the model could choose among all three options; between 18,000 feet and the fiber crossover point, which earlier versions of the model set at 24,000 feet, the model could choose between fiber and T-1, and above the fiber crossover point, the model would always use fiber. In the HAI model, T-1 technology is used to serve very small outlier clusters in locations where the copper distribution cable would exceed 18,000 feet.

78. In the *Inputs Further Notice*, we tentatively concluded that the T-1 option in the model should not be used at this time.[188] We noted that the only input values for T-1 costs on the record were the HAI default values and tentatively found that, because the model and HAI model use T-1 differently, it would be inappropriate to use the T-1 technology in the model based on these input values.[189] We also noted that the BCPM sponsors and other LECs maintained that T-1 was not a forward-looking technology and therefore should not be used in the model.[190] Other sources indicated that advanced technologies, such as HDSL, could be used to transmit information at T-1 or higher rates.[191] We sought comment on this issue.[192] We also sought comment on the extent to which HDSL technology presently is being used to provide T-1 service.[193]

79. We conclude that the T-1 option should not be employed in the current version of the model. We agree with those commenters addressing this issue that traditional T-1 using repeaters at 6000 foot intervals is not a forward-looking technology.[194] While HDSL and other DSL variants are forward-looking technologies, we do not at this time have

[188] *Inputs Further Notice* at para. 61.

[189] *Inputs Further Notice* at para. 61.

[190] *Inputs Further Notice* at para. 59.

[191] HDSL (high data rate digital subscriber line) transmits 1.544 Mbps or 2.048 Mbps in bandwidths ranging from 80 kilohertz (kHz) to 240 kHz, rather than in a bandwidth of 1.5 megahertz (mHz) required for traditional T-1 services. *See* www.adsl.com/general_tutorial.

[192] *Inputs Further Notice* at para. 60.

[193] *Inputs Further Notice* at para. 60.

[194] *See e.g.*, GTE *Inputs Further Notice* comments at 62; SBC *Inputs Further Notice* comments at 7; AT&T and MCI *Inputs Further Notice* comments at 11; AT&T and MCI *Inputs Further Notice* reply comments at 12-13. We note that, notwithstanding their support for the decision to not use T-1, AT&T and MCI encourage the Commission to modify the model to use T-1 technology in the same manner as does the HAI model, i.e., as a distribution alternative where, after using a fiber fed integrated digital loop carrier to link a main cluster of customer locations with a serving wire center, outlying customer locations beyond 18,000 feet from the main cluster's center are served by copper T-1 distribution loops. This recommendation, which would represent a platform change, will be considered in the upcoming proceeding on future changes to the model.

sufficient information to determine appropriate input values for these technologies for use in the model. We conclude, therefore, that use of T-1 in the optimization routine as an alternative to analog copper or digital fiber feeder for certain loops under 24,000 feet is not appropriate at this time.[195] Accordingly, the model will be run for universal service purposes with the T-1 option disabled.

3. Distance Calculations and Road Factor

80. In the distribution and feeder computations within the model, costs for cable and structure are computed by multiplying the route distances by the cost per foot of the cable or the structure facility, which depends on capacity and terrain factors. Distances between any two points in the network are computed using either of two distance functions.[196] The model allows a separate road factor for each distance function, and every distance measurement made in the model is multiplied by the designated factor. Road factors could be computed by comparing average distances between geographic points along actual roads with distances computed using either of the two distance functions. Given sufficient data, these factors could be computed at highly disaggregated levels, such as the state, county, or individual wire center.

81. In the *Inputs Further Notice*, we tentatively concluded that the model should use rectilinear distance in calculating outside plant distances, rather than airline distance, because rectilinear distance more accurately reflects the routing of telephone plant along roads and other rights of way.[197] We also tentatively concluded that the road factor in the model, which reflects the ratio between route distance and road distance, should be set equal to one.[198] In addition, we asked whether we should use airline miles with wire center specific

[195] SBC and GTE responded to our inquiry regarding the use and extent of advanced technologies to transmit information at T-1 on higher rates. SBC maintains that it is not reasonable to expect that HDSL will be used on T-1 technology. SBC *Inputs Further Notice* comments at 7. SBC explains that HDSL is being considered primarily for small pair gain (DLC) activation to meet specific customer needs or HI-CAP provisioning, and not for normal DLC activation. GTE maintains that HDSL can be and is used to provide 1.544 Megabit per second data rates over embedded copper plant, but its use is not an appropriate forward-looking technology. GTE *Inputs Further Notice* comments at 62. GTE adds that predominant uses of HDSL are to provision "short fuse" 1.544 Mbps service requests and extend the life of the embedded copper network. In sum, SBC and GTE assert that, even if augmented by advanced technology such as HDSL, T-1 is still not a forward-looking technology.

[196] A rectilinear measurement computes the distance between two points by constructing a rectangle with the two points as opposite vertices and measuring the distance of two adjacent sides of the rectangle. The airline distance is the length of the diagonal line that directly connects the two points.

[197] *Inputs Further Notice* at para. 62.

[198] *Inputs Further Notice* at para. 62.

road factors as an alternative to rectilinear distance.[199]

82. We reaffirm our tentative conclusion that the model should use rectilinear distance rather than airline distance in calculating outside plant distances.[200] As we noted in the *Inputs Further Notice*, research suggests that, on average, rectilinear distance closely approximates road distances.[201] We agree with SBC that the calculation of outside plant distances should reflect the closest approximation to actual route conditions and road distance.[202] We also conclude that it would be inappropriate to use airline distance in the model without simultaneously developing a process for determining accurate road factors (which would be uniformly greater than or equal to 1 in this case). While the use of geographically disaggregated road factors may merit further investigation, we note that the absence of such a data set on the record at this time precludes our ability to adopt that approach.[203] We therefore conclude that the model should use a rectilinear distance metric with a road factor of one.

C. Cable and Structure Costs

1. Background

83. The model uses several tables to calculate cable costs, based on the cost per foot of cable, which may vary by cable size (i.e., gauge and pair size) and the type of plant (i.e., underground, buried, or aerial). There are four separate tables for copper distribution and feeder cable of two different gauges, and one table for fiber cable. The engineering assumptions and optimizing routines in the model, in conjunction with the input values in the tables, determine which type of cable is used.

84. The model also uses structure cost tables that identify the per foot cost of loop structure by type (aerial, buried, or underground), loop segment (distribution or feeder), and

[199] *Inputs Further Notice* at para. 63.

[200] As BellSouth attests, cable rarely follows a straight-line "as the crow flies" route. BellSouth *Inputs Further Notice* comments, Attachment B at B-3.

[201] *Inputs Further Notice* at para. 62 n. 142 *citing* Robert F. Love *et al.*, *Facilities Location Models and Methods*, Chapter 10 (1988).

[202] SBC *Inputs Further Notice* comments at 7.

[203] We make no finding as to whether using airline miles with geographically disaggregated road factors, if available, would be a more appropriate method of calculating distances and intend to explore this issue further in the future of the model proceeding.

terrain conditions (normal, soft rock, or hard rock) for each of the nine density zones.[204]

85. After the model has grouped customer locations in clusters, it determines, based on cost minimization and engineering considerations, the appropriate technology type for the cluster and the correct size of cables in the distribution network. Every customer location is connected to the closest SAI by copper cable. The copper cable used in the local loop typically is either 24- or 26-gauge copper. Twenty-four gauge copper is thicker and, therefore, is expected to be more expensive than 26-gauge copper. Twenty-four gauge copper also can carry signals greater distances without degradation than 26-gauge copper and, therefore, is used in longer loops. In the model, if the maximum distance from the customer to the SAI is less than or equal to the copper gauge crossover point, then 26-gauge cable is used. Feeder cable is either copper or fiber. Fiber is used for loops that exceed 18,000 feet, the maximum copper loop length permitted in the model, as determined in the *Platform Order*.[205] When fiber is more cost effective, the model will use it to replace copper for loops that are shorter than 18,000 feet.

86. In the *1997 Further Notice*, the Commission sought comment on the input values that the model should use for cable and installation costs.[206] The Commission specifically sought comment on the accuracy of the default values in the BCPM and HAI models and encouraged companies to submit data to support their positions.[207] The Commission tentatively concluded that cable material and installation costs should be separately identified by both density zone and terrain type.[208] Because the Commission had received no documentation confirming that feeder and distribution cable installation costs should differ, the Commission tentatively concluded that the federal mechanism should adopt

[204] The nine density zones (measured in terms of the number of lines per square mile) are as follows: (1) zero - 4.99; (2) 5 - 99.99; (3) 100 - 199.99; (4) 200 - 649.99; (5) 650 - 849.99; (6) 850 - 2549.99; (7) 2550 - 4999.99; (8) 5000 - 9,999.99; (9) 10,000+.

[205] *Platform Order*, 13 FCC Rcd at 21352-53, para. 70.

[206] *1997 Further Notice*, 12 FCC Rcd at 18544.

[207] *1997 Further Notice*, 12 FCC Rcd at 18544. The BCPM and HAI default values are the default input values for the user-adjustable input values in the BCPM and HAI models, respectively. Although we had chosen a model platform and were no longer considering adoption of the BCPM and HAI models, we continued to consider the BCPM and HAI default input values for the inputs to be used in the model. As we explained in the *Inputs Further Notice*, for some inputs, these were the only values on the record. *Inputs Further Notice* at para. 51 n. 125. We also noted that although the BCPM model includes nationwide default values, the BCPM sponsors generally advocated the use of company-specific values and, in some cases, proposed such values.

[208] *1997 Further Notice*, 12 FCC Rcd at 18544.

HAI's assumption that such costs are identical.[209]

87. The Commission also sought comment and adopted tentative findings and conclusions relating to the cost of outside plant structure in the *1997 Further Notice*.[210] The Commission directed the HAI and BCPM sponsors to justify fully their default values for their mix of aerial, underground, and buried structure (i.e., plant mix) and sought comment on the input values that will accurately reflect the impact of varying terrain conditions on costs.[211] The Commission noted that "recent installations of outside structure may more closely meet forward-looking design criteria than do historical installations."[212] The Commission found that an efficient carrier will vary its plant mix according to the population density of an area and tentatively concluded that the assignment of plant mix defined by the model should reflect both terrain factors and line density zones.[213]

88. In the *Inputs Public Notice*, the Bureau sought comment on the analysis of David Gabel and Scott Kennedy of data from the Rural Utilities Service (RUS) regarding cable and structure costs.[214] On December 11, 1998, the Bureau held a public workshop designed to elicit comment on the input values for materials costs.[215] At the workshop, Dr. Gabel presented the methodology used by the Commission staff to derive preliminary values for cable costs for non-rural LECs based on his earlier analysis of the RUS data.

89. We sought to supplement the record with respect to cable and structure costs by requesting additional data from LECs, including competitive LECs, in the form of a voluntary survey of structure and cable costs.[216] Ten companies eventually responded to the survey.[217]

[209] *1997 Further Notice*, 12 FCC Rcd at 18544.

[210] *1997 Further Notice*, 12 FCC Rcd at 18541.

[211] *1997 Further Notice*, 12 FCC Rcd at 18541.

[212] *1997 Further Notice*, 12 FCC Rcd at 18541.

[213] *1997 Further Notice*, 12 FCC Rcd at 18541.

[214] *Inputs Public Notice* at 7. *See* David Gabel and Scott Kennedy, *Estimating the Cost of Switching and Cables Based on Publicly Available Data*, National Regulatory Research Institute NRRI 98-09, April 1998, (NRRI Study). Dr. Gabel and Mr. Kennedy are consultants for the Commission in this proceeding.

[215] *See Workshop Public Notice*.

[216] After numerous discussions with industry during development of the survey, we distributed a final version on December 14, 1998, and requested responses by January 14, 1999.

2. Nationwide Values

90. As discussed in this section, we adopt nationwide average values for estimating cable and structure costs in the model rather than company-specific values.[218] In reaching this conclusion, we reject the explicit or implicit assumption of most LEC commenters that company-specific values, which reflect the costs of their embedded plant, are the best predictor of the forward-looking cost of constructing the network investment predicted by the model. We find that, consistent with the *Universal Services Order's* third criterion, the forward-looking cost of constructing a plant should reflect costs that an efficient carrier would incur, not the embedded cost of the facilities, functions, or elements of a carrier.[219] We recognize that variability in historic costs among companies is due to a variety of factors and does not simply reflect how efficient or inefficient a firm is in providing the supported services. We reject arguments of the LECs, however, that we should capture this variability by using company-specific data rather than nationwide average values in the model. We find that using company-specific data for federal universal service support purposes would be administratively unmanageable and inappropriate. Moreover, we find that averages, rather than company-specific data, are better predictors of the forward-looking costs that should be supported by the federal high-cost mechanism. Furthermore, we note that we are not attempting to identify any particular company's cost of providing the supported services. We are estimating the costs that an efficient provider would incur in providing the supported services.

91. AT&T and MCI agree that nationwide input values generally should be used for the input values in the model.[220] AT&T and MCI concur with our tentative conclusion that the use of nationwide values is more consistent with the forward-looking nature of the high-cost model because it mitigates the rewards to less efficient companies. Additionally, AT&T and MCI maintain that developing separate inputs values on a state-specific, study-area specific, or holding company-specific basis is not practicable. As AT&T and MCI contend,

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[217] BellSouth, Ameritech, Pacific Bell, Nevada Bell, Southwestern Bell, Sprint, GTE, Aliant, SNET, and AT&T submitted data in response to the structure and cable cost survey. Several companies requested additional time to complete and submit their data. After receiving and reviewing the data, staff found that, despite detailed survey instructions, further discussions with a number of companies were required before we could assemble the data for comparison and analysis. In a number of cases, respondents filed revised data or clarified the data they had submitted.

[218] *See also supra* paragraphs 29-32 and *infra* paragraph 348 for further discussion of the adoption of nationwide average values for estimating costs and expenses in the model.

[219] *Universal Service Order*, 12 FCC Rcd at 8913, para. 250.

[220] AT&T and MCI *Inputs Further Notice* reply comments at 3.

doing so would be costly and administratively burdensome.

92. While reliance on company-specific data may be appropriate in other contexts, we find that for federal universal service support purposes it would be administratively unmanageable and inappropriate. The incumbent LECs argue that virtually all model inputs should be company-specific and reflect their individual costs, typically by state or by study area.[221] For example, GTE claims that the costs that an efficient carrier incurs to provide basic service vary among states and even among geographic areas within a state.[222] GTE asserts that the only way for the model to generate accurate estimates, i.e., estimates that reflect these differences, is to use company-specific inputs rather than nationwide input values. As parties in this proceeding have noted, however, selecting inputs for use in the high-cost model is a complex process. Selecting different values for each input for each of the fifty states, the District of Columbia, and Puerto Rico, or for each of the 94 non-rural study areas, would increase the Commission's administrative burden significantly. Unless we simply accept the data the companies provide us at face value, we would have to engage in a lengthy process of verifying the reasonableness of each company's data. For example, in a typical tariff investigation or state rate case, regulators examine company data for one time high or low costs, pro forma adjustments, and other exceptions and direct carriers to adjust their rates accordingly. Scrutinizing company-specific data to identify such anomalies and to make the appropriate adjustments to the company-proposed input values to ensure that they are reasonable would be exceedingly time consuming and complicated given the number of inputs to the model.

93. Where possible, we have tried to account for variations in costs by objective means. As explained below, the model reflects differences in structure costs by using different values for the type of plant, the density zone, and geological conditions. As discussed below, we sought comment in the *Inputs Further Notice* on alternatives to nationwide plant mix values, but the algorithms on the record produce biased results. We continue to believe that varying plant mix by state, study area, or region of the country may more accurately reflect variations in forward-looking costs and intend to seek further comment on this issue in the future of the model proceeding.

3. Preliminary Cable Cost Issues

[221] *See, e.g.,* Bell Atlantic *Inputs Further Notice* comments at 20-21; BellSouth *Inputs Further Notice* comments, Attachment B at B-16, B-18; GTE *Inputs Further Notice* comments at 10-11; Ameritech *Inputs Further Notice* comments at 8; Sprint *Inputs Further Notice* comments at 3-7.

[222] GTE *Inputs Further Notice* comments at 10-11. *See also* BellSouth *Inputs Further Notice* comments, Attachment A at A-5, A-8 - A-14.

94. Use of 24-gauge and 26-gauge Copper. In the *Inputs Further Notice*, we tentatively concluded that the model should use both 24-gauge and 26-gauge copper in all available pair-sizes.[223] We based our tentative conclusion on a preliminary analysis of the results of the structure and cable cost survey, in which it appeared that a significant amount of 24-gauge copper cable in larger pair sizes currently is being deployed. We also noted that, while HAI default values assume that all copper cable below 400 pairs in size is 24-gauge and all copper cable of 400 pairs and larger is 26-gauge, the BCPM default values include separate costs for 24- and 26-gauge copper of all sizes.[224]

95. We conclude that the model should use both 24-gauge and 26-gauge copper in all available pair sizes. No commenter refuted our observation that a significant amount of 24-gauge copper cable in larger pair sizes currently is being deployed. Those commenters addressing this issue concur with our tentative conclusion.[225] SBC confirms our analysis of the survey data and notes that it deploys 24-gauge cable in sizes from 25 to 2400 pairs.[226] GTE explains, and we agree, that the model should use both 24-gauge and 26-gauge copper in all available pair sizes in order to stay within transmission guidelines when modeling 18 kilofoot loops.[227]

96. Distinguishing Feeder and Distribution Cable Costs. In the *Inputs Further Notice*, we reaffirmed the Commission's tentative conclusion in the *1997 Further Notice* that the same input values should be used for copper cable whether it is used in feeder or in distribution plant.[228] We adopt this tentative conclusion. Those commenters addressing this issue agree with our tentative conclusion.[229] GTE contends that it is both unnecessary and

[223] *Inputs Further Notice* at para. 65.

[224] *Inputs Further Notice* at para. 65 n. 145 *citing* HAI Inputs Portfolio at 20.

[225] *See e.g.*, AT&T and MCI *Inputs Further Notice* comments at 13; GTE *Inputs Further Notice* comments at 47-48; Sprint *Inputs Further Notice* comments at 17-18; SBC *Inputs Further Notice* comments at 7-8.

[226] SBC *Inputs Further Notice* comments at 8.

[227] GTE *Inputs Further Notice* comments at 47. GTE asserts that it believes that, even for 12 kilofoot loops, a significant amount of 24-gauge cable will continue to be deployed in the network because of certain cost-saving reasons related to its larger diameter.

[228] *Inputs Further Notice* at para. 66.

[229] *See e.g.*, GTE *Inputs Further Notice* comments at 48; Sprint *Inputs Further Notice* comments at 18; SBC *Inputs Further Notice* comments at 8.

inappropriate to have different costs for feeder and distribution cable material.[230] GTE explains that, although quantities of material and labor related to cable size may differ between feeder and distribution, the unit costs for each remain the same.[231] Similarly, Sprint agrees that the material cost of cable is the same whether it is used for distribution or feeder.[232] In sum, we find that the record demonstrates that it is appropriate to use the same input values for copper cable whether it is used in feeder or in distribution plant.

97. Distinguishing Underground, Buried, and Aerial Installation Costs. In the *Inputs Further Notice*, we also tentatively concluded that we should adopt separate input values for the cost of aerial, underground, and buried cable.[233] We reached this tentative conclusion on the basis of our analysis of cable cost data supplied to us in response to data requests and through *ex parte* presentations. We found considerable differences in the per foot cost of cable, depending upon whether the cable was strung on poles, pulled through conduit, or buried.

98. We conclude that separate input values for the cost of aerial, underground, and buried cable should be adopted. Those commenters addressing this issue confirm our analysis of the data, i.e., that there are differences, some significant, in placement costs for aerial, underground, and buried cable.[234] GTE explains that, from a material perspective, the cable may have different protective sheathing, depending on construction applications.[235] GTE adds that labor costs also differ depending on the type of placement.[236] Both SBC and Sprint identify the cost of labor as varying significantly depending upon the type of placement.[237] Based upon a review of the record in this proceeding, we conclude that separate input values

[230] GTE *Inputs Further Notice* comments at 47. *See also* SBC *Inputs Further Notice* comments at 8. SBC contends that the same input values should be used as long as density values, which reflect costs differences in varying degrees of urban and suburban construction, are properly reflected.

[231] GTE *Inputs Further Notice* comments at 47.

[232] Sprint *Inputs Further Notice* comments at 17. Sprint contends however that in actual practice, splicing costs may be somewhat higher for distribution cable due to such factors as more frequent tapering of cable sizes and branch splices, but this difference is not material for modeling purposes.

[233] *Inputs Further Notice* at para. 68.

[234] *See e.g.*, GTE *Inputs Further Notice* comments at 48; SBC *Inputs Further Notice* comments at 8; Sprint *Inputs Further Notice* comments at 18. *See also* AT&T and MCI *Inputs Further Notice* comments at 13.

[235] GTE *Inputs Further Notice* comments at 48.

[236] GTE *Inputs Further Notice* comments at 48.

[237] SBC *Inputs Further Notice* comments at 8; Sprint *Inputs Further Notice* comments at 18.

for the cost of aerial, underground, and buried cable are, therefore, warranted.

99. Deployment of Digital Lines. We also conclude that two inputs, "pct_DS1" and "pct_1sa", should be modified to provide more accurate deployment of digital lines in the distribution plant. The model can deploy a portion of distribution plant on digital DS1 circuits by specifying these two user adjustable inputs. The input "pct_DS1" determines the percentage of switched business traffic carried on DS1 circuits, and the input "pct_1sa" determines the percentage of special access lines carried on DS1 circuits. Previously, we used default values for the inputs "pct_DS1" and "pct_1sa." We now adopt more accurate values for these inputs using 1998 line count data, following the methodology described below.

100. Initially the model determines the number of special access lines from a "LineCount" table in the database "hcpm.mdb," which provides for each wire center the number of residential lines, business lines, special access lines, public lines, and single business lines.[238] The Commission required incumbent LECs to provide line counts for business switched and non-switched access lines on a voice equivalent basis[239] and on a facilities basis.[240] Upon receipt of those filings, we determined industry totals for each of the line count items requested.[241] By applying the model's engineering conventions to the totals, the model determines the percentage of switched and non-switched lines provided as DS1-type service.[242] Thus, using the channel and facility counts submitted in response to the *1999 Data Request*, it is possible to determine the "pct_DS1" input value using the following formula: (1-pct_DS1)*channels + pct_DS1*channels/12 = facilities.[243] A similar calculation is performed to solve for the "pct_1sa" input value. For both switched business and special access lines, the number of digital lines is then determined by multiplying the respective line count by the input value "pct_DS1" or "pct_1sa." Since 24 communications channels can be carried by two pairs of copper wires, the number of copper cables required to carry digital traffic is computed by dividing the number of digital channels by 12. These percentages are

[238] By model convention, business lines are reported as switched business lines.

[239] For example, DS1 service provides 24 voice equivalent channels using two copper pairs.

[240] *See Federal-State Joint Board on Universal Service, Forward-Looking Mechanism for High Cost Support for Non-Rural LECs*, Order, CC Docket Nos. 96-45, 97-160, DA 99-1406 (rel. July 19, 1999) (*1999 Data Request*).

[241] For these line count totals, we only use data from the responses that we found to be consistent with the definitions prescribed in the *1999 Data Request*. Submissions in which companies reported more facilities than channels are inconsistent with those definitions and do not reflect current industry practice.

[242] We note that only DS0 or DS1 service is provided under the model's conventions. The model does not allow for the deployment of DS2 or DS3 services.

[243] This equation is applied separately for switched and non-switched lines.

used to adjust the wire center cable requirements by reducing the facilities needed to serve multi-line business and special access customers.

4. Cost Per Foot of Cable

a. Background

101. In the *Inputs Further Notice*, we tentatively concluded that we should use, with certain modifications, the estimates in the NRRI Study, *Estimating the Cost of Switching and Cables Based on Publicly Available Data*, for the per-foot cost of aerial, underground, and buried 24-gauge copper cable.[244] Concomitantly, we tentatively concluded that we should use, with certain modifications, the estimates in the NRRI Study for the per-foot cost of aerial, underground, and buried fiber cable.[245]

102. In reaching these conclusions, we rejected the default input values for cable costs provided by both the HAI and BCPM sponsors which are based upon the opinions of their respective experts, because they lacked additional support that would have enabled us to substantiate those opinions.[246] We also noted that we had received cable cost data from a number of LECs, including data received in response to the structure and cable cost survey, and were in the process of scrutinizing it.[247]

103. The HAI sponsors supported using the publicly available RUS data in the NRRI Study to estimate cable costs and structure costs.[248] In contrast, Sprint questioned the reliability and suitability of these data, and urged us instead to use the cable cost data provided by incumbent LECs.[249] Sprint pointed out that the RUS data only reflect information from the two lowest density zones.[250] Sprint explained that because longer loops are used in sparsely populated areas, lower-gauge copper often is used. We explained that

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[244] *Inputs Further Notice* at para. 72; *See also Inputs Further Notice* at 77, 82-83. As noted in paragraph 88 *supra*, this study provides a methodology for estimating cable and structure costs.

[245] *Inputs Further Notice* at paras. 90, 92, 94.

[246] *Inputs Further Notice* at para. 69.

[247] *Inputs Further Notice* at para. 69.

[248] *See Inputs Further Notice* at para. 71 n. 152 *citing* Letter from Chris Frentrup, MCI Worldcom, to Magalie Roman Salas, FCC, dated Feb. 9, 1999 (MCI Feb. 9, 1999 *ex parte*).

[249] *See Inputs Further Notice* at para. 71 n. 153 *citing* Letter from Pete Sywenki, Sprint, to Magalie Roman Salas, FCC, dated Jan 29, 1999 (Sprint Jan. 29, 1999 *ex parte*).

[250] *See Inputs Further Notice* at para 71 n. 154 *citing* Sprint Jan. 29, 1999 *ex parte* at 8-9.

Sprint had mischaracterized the analysis of the RUS data in the NRRI Study. We noted for example, that Sprint challenged the validity of the study because some of the observations have zero values for labor or material, while failing to recognize that these values were excluded from Gabel and Kennedy's regression analysis.[251] Similarly, we found that Sprint's complaint that Gabel and Kennedy do not analyze separately the components of total cable costs, labor and material, overlooked the fact that Gabel and Kennedy's regression analysis is designed to explain the variation in total costs.[252]

104. Moreover, in reaching our tentative conclusion to use the NRRI Study and the underlying data from the two lowest density zones, i.e., rural areas, to estimate cable costs for non-rural LECs, we noted that none of the parties proposed cable cost values that vary by density zones. Nor did the models considered by the Commission have the capability of varying cable costs by density zones.[253]

b. Discussion

105. We affirm our tentative conclusion that we should use, with certain modifications as described more fully below, the estimates in the NRRI Study for the per-foot cost of aerial, underground, and buried 24-gauge copper cable and for the per-foot cost of aerial, underground, and buried fiber cable. We conclude that, on balance, these estimates, as modified in the *Inputs Further Notice*, and further adjusted herein, are the most reasonable estimates of the per-foot cost of aerial, underground, and buried 24-gauge copper cable and fiber cable on the record before us. In reaching this conclusion, we reject, for the reasons enumerated below, the arguments of those commenters who contend that we should use company-specific data to develop the inputs for the per-foot cost of cable to be used in the model.[254]

106. <u>Company-specific data</u>. As we discussed above, we have determined to use nationwide average input values for estimating outside plant costs.[255] In reaching this conclusion, we determined that the use of company-specific inputs was inappropriate because of the difficulty in verifying the reasonableness of each company's data, among other reasons. We have examined cable cost and structure cost data received from a number of non-rural

[251] *Inputs Further Notice* at para. 73 n. 156 *citing* Sprint Jan. 29 *ex parte*, Attachment at 5.

[252] *Inputs Further Notice* at para. 73 n. 157 *citing* Sprint Jan. 29 *ex parte*, Attachment at 7.

[253] *Inputs Further Notice* at para. 73.

[254] *See e.g.*, Bell Atlantic *Inputs Further Notice* comments at 18; GTE *Inputs Further Notice* comments at 48; BellSouth *Inputs Further Notice* comments, Attachment B at B-7 - B-11.

[255] *See supra* paragraph 29-32 and 90-93.

LECs, as well as AT&T, in response to the structure and cable cost survey and through a series of *ex parte* filings. In addition, we have examined additional company-specific data submitted by certain parties with their comments. As discussed more fully below, we conclude that these data are not sufficiently reliable to use to estimate the nationwide input values for cable costs or structure costs to be used in the model.[256]

107. We conclude that the cable cost and structure cost data received in response to the structure and cable cost survey, in the *ex parte* filings, and in the comments are not verifiable. We find that with regard to the survey data, notwithstanding our request, most respondents did not trace the costs submitted in response to the survey from dollar amounts set forth in contracts by providing copies of these contracts and all of the interim calculations for a single project or a randomly selected central office. With regard to the *ex parte* data and data submitted with the comments, we find that, because most respondents did not document in sufficient detail the methodology, calculations, assumptions, and other data used to develop the costs they submitted, nor did they submit contracts or invoices setting forth in detail the cable and structure costs they incurred, these data cannot be substantiated.[257] Moreover, we note that the structure and cable costs reported in the survey by some parties differ significantly from those reported by the same parties in the *ex parte* filings. These differences are not explained, and render those sets of data unreliable.

108. We find this lack of back-up information particularly unsettling given the magnitude of certain of the costs reported. We agree with AT&T and MCI that the cable installation costs submitted by the incumbent LECs appear to be high.[258] We also agree with AT&T and MCI that this is because the loading factors employed in calculating these costs appear to be overstated. Because of the lack of back-up information to explain these loading costs, however, there is no evidence on the record to controvert our initial assessment. Accordingly, the level of these costs remains suspect.

109. Moreover, we find additional deficiencies beyond the critical lack of substantiating data, impugning the reliability of the LEC survey data and the *ex parte* data we have received. As discussed above, the task of the model is to calculate forward-looking

[256] The following discussion reaches conclusions with regard to the use of company-specific data in the estimation of cable costs inputs. Such information was received initially, in conjunction with structure costs data, in response to our survey on cable and structure costs. Because we find that the data for cable costs and structure costs suffers from the same deficiencies, we also reach conclusions with regard to the use of such data in the estimation of structure cost inputs.

[257] In reaching this conclusion we also take note of AT&T and MCI's inability to link the incumbents LECs actual contract costs and the data they submitted to the Commission. AT&T and MCI *Inputs Further Notice* comments at 15 (Proprietary Version).

[258] AT&T and MCI *Input Further Notice* comments at 15 (Proprietary Version).

costs of constructing a wireline local telephone network. To that end, the survey directed respondents to submit cable and structure costs for growth projects for which expenditures were at least $50,000.[259] We believed that such projects would best reflect the costs that a LEC would incur today to install cable if it were to construct a local telephone network using current technology. In contrast, absent from the data would be costs associated with maintenance or projects of smaller scale which do not represent the costs of installing cable during such construction using current technology. Thus, the data would capture the economies of scale enjoyed on large projects which, should result in lower cable costs on a per-foot basis. Notwithstanding the survey directions, several of the respondents submitted data representing projects that were not growth projects or projects for which expenditures were less than the $50,000 minimum we established.

110. Conversely, some respondents included costs that should have been excluded under the definitions employed in the survey. For example, some respondents included costs for terminating structures, such as cross-connect boxes, in the cable costs they reported. Similarly, some respondents reported underground structure costs on a "per duct foot" basis contrary to the instructions set forth in the survey directing that such costs be reported on a "per foot" basis. We find that these inconsistencies render the use of the survey data inappropriate.

111. In sum, we find that certain of the concerns we identified with regard to using company-specific data, rather than nationwide average inputs for model inputs, have been borne out in our review of the cable cost and structure cost data we have reviewed. Specifically, we find that we are unable to verify the reasonableness of such data. Accordingly, we find that we are unable to use the company-specific data we have received for the estimation of cable cost and structure cost inputs for the model.

112. In reaching this conclusion, we reject the contention that the inability to link the costs submitted in response to the cable and structure cost survey to contracts is irrelevant because the survey request was not intended to create such a trail.[260] This claim ignores the fact that the reasonableness of the survey data was placed into question by the presence of data received on the record that was inconsistent with the survey data. For this reason, as GTE attests, we attempted to create such a trail by requesting contracts and other supporting data in an effort to verify the reasonableness of the company-specific data received in response to the survey as well as in *ex parte* filings.[261]

[259] *Inputs Further Notice*, Appendix C, section III.C.

[260] GTE *Inputs Further Notice* reply comments at 27.

[261] As GTE explains in its comments, GTE submitted additional information as a follow-up to our original request. GTE submitted such information in response to a request from the Bureau.

113. Methodology. As we explained in the *Inputs Further Notice*, our tentative decision to rely on the NRRI Study was predicated on our inability to substantiate the default input values for cable costs and structure costs provided by the HAI and BCPM sponsors.[262] For that reason, we tentatively concluded, in the absence of more reliable evidence of cable and structure costs for non-rural LECs, to use estimates in Gabel and Kennedy's analysis of RUS data, subject to certain modifications, to estimate cable and structure costs for non-rural LECs. As we explained, Gabel and Kennedy first developed a data base of raw data from contracts for construction related to the extension of service into new areas, and reconstruction of existing exchanges, by rural-LECs financed by the RUS. Gabel and Kennedy then performed regression analyses, using data from the HAI model on line counts and rock, soil, and water conditions for the geographic region in which each company in the database operates to estimate cable and structure costs.[263] Regression analysis is a standard method used to study the dependence of one variable, the dependent variable, on one or more other variables, the explanatory variables. It is used to predict or forecast the mean value of the dependent variable on the basis of known or expected values of the explanatory variables.[264]

114. Those commenters advocating the use of company-specific data provide a litany of alleged weaknesses and flaws in the NRRI Study, and the modifications we proposed, to discredit its use to estimate the input values for cable costs and structure costs. In sum, they argue that the overall approach we proposed is unsuitable for estimating the cable and structure costs of non-rural LECs and generally leads to estimates which understate actual forward-looking costs.[265] As discussed below, we find the contentions in support of this claim unpersuasive. Significantly, we note that these commenters provide no evidence that substantiates the reasonableness of the company-specific cable costs and structure costs submitted on the record to permit their use as an alternative in the estimation of cable and structure cost inputs to be used in the model.[266]

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[262] *Inputs Further Notice* at paras. 69-74, 105. As noted above, we had received data in response to the cable and structure cost survey and, at the time of the *Inputs Further Notice*, were in the process of scrutinizing it.

[263] NRRI Study at 34-36.

[264] For a discussion of regression analysis, *See* William H. Greene, *Econometric Analysis* (1990).

[265] *See e.g.*, GTE *Inputs Further Notice* comments at 13-33; Bell Atlantic *Inputs Further Notice* comments at 15-19; BellSouth *Inputs Further Notice* comments, Attachment A at A-2 - A-5, Attachment B at B-1 - B-14; US West *Inputs Further Notice* comments, Attachment A at 2-29; Sprint *Inputs Further Notice* comments at 5-7, 17-33.

[266] As discussed in more detail below, we have relied on contract data in the estimation of input values for the costs of DLCs and *ex parte* data in the estimation of input values for the costs of SAIs. As explained in paragraphs 253-254 and 274-275, such data is the only reliable data available on the record for the determination of such costs.

115. For similar reasons, we reject AT&T and MCI's recommendation that we rely on the RUS data to develop cost estimates for the material cost of cable and then adopt "reasonable" values for the costs of cable placing, splicing, and engineering based on the expert opinions submitted by AT&T and MCI in this proceeding.[267] We find that the expert opinions on which AT&T and MCI's proposed methodology relies lack additional support that would permit us to substantiate those opinions. Moreover, as discussed in more detail below, we reject AT&T and MCI's contentions, often analogous to those raised by the non-rural LECs, that the approach we proposed to estimate cable and structure costs is flawed in certain respects.

116. We reject the contentions of the commenters, either express or implied, that it is inappropriate to employ the NRRI Study because the RUS data set on which it relies is not a sufficiently reliable data source for structure and cable costs. We find that the RUS data set is a reasonably reliable source of absolute cable costs and structure costs, and more reliable and verifiable than the company-specific data we have reviewed. As explained in the NRRI Study, and noted above, the RUS data reflect contract costs for construction related to the extension into new areas, and reconstruction of existing exchanges, by rural LECs financed by the RUS.[268] Thus, the RUS data reflect actual costs derived from contracts between LECs and vendors. These costs are not estimates, but actual costs. Nor do they reflect only the opinions of outside plant engineers. In sum, we conclude that these are verifiable data.

117. We also note that the RUS data reflect the costs from 171 contracts covering 57 companies operating in 27 states adjusted to 1997 dollars.[269] These companies operate in areas that have different terrain, weather, and density characteristics. This fact makes the RUS data sample suitable for econometric analysis. Moreover, we find that, because the costs are for construction that must abide by the engineering standards established by the RUS, these data are consistent. We note also that the imposition of consistent engineering requirements mitigate the impact of any inefficiencies or inferior technologies that may otherwise be reflected in the data.

118. Finally, as noted above, the RUS data reflect costs for additions to existing plant or new construction. The use of such costs is consistent with the objective of the model to identify the cost today of building an entire network using current technology.

119. In reaching our conclusion to use the NRRI Study and thus the underlying RUS data, we have considered and rejected the contentions of the commenters that the RUS data

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[267] AT&T and MCI *Inputs Further Notice* comments at 15-16.

[268] NRRI Study at 2.

[269] NRRI Study at 2.

set is flawed thereby rendering use of the NRRI Study inappropriate. GTE claims that because certain high-cost observations were removed from the RUS data, the NRRI Study's results are unrepresentative of rural companies' costs, and are even less representative of non-rural companies' costs.[270] We disagree. Gabel and Kennedy omitted data reflecting certain contracts from the RUS data they used to develop cost estimates because estimates produced using the data were inconsistent with the values of such estimates suggested by *a priori* reasoning or evidence.[271] For example, they excluded certain observations from the buried copper and structure regression analysis because buried copper cable and structure estimates obtained from this analysis would otherwise be higher in low density areas than in higher density areas. Such a result is contrary to the information contained in the more than 1000 observations reflected in the data from which Gabel and Kennedy developed their buried copper cable and structure regression equation. Thus, removing the observations does not render the remaining data set less representative of rural companies' costs or, as adjusted below, the estimates of the costs of non-rural companies. Moreover, we note that the evidence supplied on the record in this proceeding demonstrates that structure costs increase as population density increases. Thus, we find that the RUS data set is not flawed as GTE contends. We conclude that the removal of certain high cost observations was reasonable.

120. We also disagree with GTE's and Bell Atlantic's assertion that the NRRI Study is flawed because the RUS company contracts do not reflect actual unit costs for work performed, but rather the total cost for a project.[272] Both commenters claim that this alleged failure results in unexplained variations in the RUS data which undermine the validity of the estimates produced. Contrary to GTE's and Bell Atlantic's contention, the contracts from which Gabel and Kennedy developed their data base for developing structure and cable costs do set forth per unit costs for materials and per unit costs for specific labor tasks.[273]

121. We also disagree with AT&T and MCI's claim that the RUS data are defective because they consist of primarily small cables.[274] AT&T and MCI claim that 74 percent of the RUS data are for cables of 50 pairs or less, and 95 percent are for cable sizes of 200 pairs or less. As a result, AT&T and MCI contend that the RUS data are inaccurate, especially for cable sizes above 200 pairs. We disagree with AT&T and MCI's analysis. We note that, for the buried copper cable and structure regression equations we proposed and adopt,

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[270] GTE *Inputs Further Notice* comments at 15-16.

[271] NRRI Study at 37-40.

[272] GTE *Inputs Further Notice* comments at 17-19; Bell Atlantic *Inputs Further Notice* comments at 16, Attachment C at 9.

[273] NRRI Study at 8-9 and 67-73.

[274] AT&T and MCI *Inputs Further Notice* comments at 14.

approximately 39 percent of the observations are for cable sizes of 50 pairs or less, and approximately 76 percent are for 200 pairs or less. For the underground copper cable regression equation we proposed and adopt, approximately 10 percent of the observations are for cable sizes of 50 pairs or less, and approximately 33 percent are for 200 pairs or less. For the aerial copper cable regression equation we proposed and adopt, approximately 40 percent of the observations are for cable sizes of 50 pairs or less, and approximately 76 percent are for 200 pairs or less. Thus, the proportion of the observations reflected in the copper cable cost estimates we adopt are significantly greater for relatively large cables than what AT&T and MCI contend.

122. Finally, we reject the contention that it is inappropriate to use the NRRI Study because the RUS data base is not designed for the purpose of developing input values for the model.[275] In the NRRI Study, Gabel and Kennedy explain that they began developing the data base as an outgrowth of the Commission's January 1997 workshop on cost proxy models when it became apparent that costs used as inputs in such models should be able to be validated by regulatory commissions. For this reason, they prepared data that is in the public domain to provide independent estimates of structure and cable costs.[276]

123. We also find unpersuasive the contention that there are econometric flaws in the NRRI Study which render it unsuitable for developing input values.[277] We disagree with the contentions of several commenters that the structure cost and cable cost regression equations that we develop from the RUS data are flawed because they are based on a relatively small number of observations.[278] As a general rule of thumb, in order to obtain reliable estimates for the intercept and the slope coefficients in a regression equation, the number of observations on which the regression is based should be at least 10 times the number of independent variables in the regression equation.[279] Ameritech claims that the sample size used to estimate the costs of buried placement is too small because it contains only 26 observations in density zone one.[280] Ameritech's criticism ignores the fact that we

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[275] *See e.g.*, Bell Atlantic *Input Further Notice* comments at 16, Attachment C at 9.

[276] NRRI Study at 1-2.

[277] *See e.g.*, GTE *Inputs Further Notice* comments at 19-22; Bell Atlantic *Inputs Further Notice* comments at 16-17, Attachment C at 13-14.

[278] *See e.g.*, GTE *Inputs Further Notice* comments at 15; Ameritech *Inputs Further Notice* comments at 26; AT&T and MCI *Inputs Further Notice* comments at 14.

[279] Richard W. Madsen and Melvin L. Moeschberger, *Statistical Concepts with Applications to Business and Economics*, 490 (2nd Edition 1986).

[280] Ameritech *Inputs Further Notice* comments at 16.

use a single regression equation to estimate buried copper cable and structure costs for density zones one and two based on 1,131 observations (1,105 in zone two and 26 in zone one). There are four independent variables in the buried copper cable and structure regression equation, i.e., the variables that indicate the size of the cable, presence of a high water table, combined rock and soil type, and density zone. This suggests that approximately 40 observations are needed to obtain reliable estimates for the parameters in this regression equation. The total number of observations used to estimate this regression equation, 1,131, readily exceeds the number suggested for estimating reliably this regression equation. The number of observations for density zone one alone, 26, provides 65 percent of the suggested number of observations. Similarly, AT&T and MCI claim that the sample size for underground cable is too small because it contains only 80 observations.[281] There is one independent variable in the adopted underground copper cable equation, i.e., the variable that indicates the size of the cable. Based on the rule of thumb noted above, 10 observations are needed to reliably estimate this regression equation. The number of observations used to estimate the adopted underground copper cable regression equation, 81, is more than eight times this suggested number.[282] Moreover, we note that Ameritech does not provide any evidence that suggest that a sample that has 26 observations in density zone 1 produces biased estimates of buried structure and cable costs for density zone one. Similarly AT&T and MCI do not provide any evidence to support their allegation that a sample size of 80 observations produces biased estimates of underground copper cable costs. Finally, we note that GTE contends that the regression results for aerial structure are undermined because the sample size for poles is based only on 19 observations.[283] While a sample of this size fails to satisfy the general rule of thumb we noted above, we find that the estimates produced are reasonable. As we pointed out in the *Inputs Further Notice*, the average material price reported in the NRRI Study for a 40-foot, class four pole is $213.94. This is close to our calculations of the unweighted average material cost for a 40-foot, class four pole, $213.97, and the weighted average material cost, by line count, $228.22, based on data submitted in response to the *1997 Data Request*. Moreover, we note that GTE does not provide any evidence that suggests that a sample size of 19 poles for developing aerial structure costs produces biased estimates as GTE seems to allege.

124. We also disagree with GTE's contention that the NRRI Study contains three methodological errors that make its results unreliable. First, GTE asserts that the most serious of these flaws is that the NRRI Study improperly averages ordinal or categorical data, i.e.,

[281] AT&T and MCI *Inputs Further Notice* comments at 14.

[282] The *Inputs Further Notice* indicated that 80 observations were used to estimate the proposed underground copper cable costs. However, 81 observations were used to develop these proposed costs. Eighty one observations are used to estimate the adopted underground copper cable costs.

[283] GTE *Inputs Further Notice* comments at 15.

qualitative values, for the costs of placing structure in different types of soil.[284] Contrary to GTE's claim, the independent variables that indicate soil type, rock hardness, and the presence of a high water table used in the regression equations for aerial and underground structure and buried structure and cable costs in the NRRI Study and proposed in the *Inputs Further Notice* do not reflect an incorrect averaging of ordinal data. The variables for soil, rock, and water indicate the average soil, rock, and water conditions in the service areas of RUS companies. They are based on averages of data obtained from the HAI database for the Census Block Groups in which the RUS companies operate. In general, the magnitude of the t-statistics for the coefficients of the independent variables for soil, rock, and water in the structure regression equations indicate that these variables have a statistically significant impact on structure costs. The magnitude of the F-statistic indicates that the independent variables in the structure regression equations, including those that indicate water, rock, and soil type, jointly provide a statistically significant explanation of the variation in structure costs. These statistical findings justify use of these variables in the structure regression equations. We also note that HAI uses as cardinal values, i.e., quantitative, not ordinal values, the soil and rock data from which the averages reflected in the rock and soil variables in the NRRI Study are calculated. For example, HAI uses a multiplier of between 1 and 4 to calculate the increase in placement cost attributable to the soil condition. Moreover, and more importantly, we note that no commenter has demonstrated the degree of, or even the direction of, any bias in the cost estimates derived in the NRRI Study or in the regression equations proposed in the *Inputs Further Notice* as a result of the use of soil, water, and rock variables based on averages of HAI data.

125. GTE also claims that the NRRI Study is flawed because it relies on the HAI model's values relating to soil type which GTE claims were "made up."[285] GTE contends that this renders the variable relating to soil type judgmental and biased. We find GTE's concern misplaced. As explained above, the econometric analyses of the data demonstrate a statistically significant relationship between the geological variables developed from the HAI data and the structure costs. Finally, we disagree with GTE's claim that the NRRI Study is flawed because of a mismatch in the geographic coverage of the RUS data and the HAI model variables.[286] GTE does not provide any evidence showing that the alleged mismatch introduces an upward or downward bias on the cost estimates obtained from the regression equations. Moreover, and more importantly, the t-statistics for the coefficients of the variables that measure rock and soil type generally indicate that these geological variables provide a statistically significant explanation of variations in RUS companies' structure costs.

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[284] GTE *Inputs Further Notice* comments at 19-21. *See also* Bell Atlantic *Inputs Further Notice* comments at 16-17, Attachment C at 13-14.

[285] GTE *Inputs Further Notice* comments at 21.

[286] GTE *Inputs Further Notice* comments at 22.

126. We also reject the claims that the derivation of the equations for 24-gauge buried copper cable, buried structure, and buried fiber cable from the NRRI Study regression equations for 24-gauge buried copper cable and structure and buried fiber cable and structure, respectively, is inappropriate.[287] As we explained in the *Inputs Further Notice*, we modified the regression equations in the NRRI Study for 24-gauge buried copper cable and structure and buried fiber cable and structure, as modified by the Huber methodology described below, to estimate the cost of 24-gauge buried copper cable, buried structure and buried fiber cable because the regression equations for buried copper cable and structure and buried fiber cable and structure provide estimates for labor and material costs for both buried cable and structure combined.[288] In layman's terms, we split the modified 24-gauge buried copper cable and structure regression equation into two separate equations, one for 24-gauge buried copper cable and one for buried structure costs. We also split the modified buried fiber cable and structure regression equation to obtain an equation for buried fiber cable.[289] We did this because the model requires a separate input for labor and material costs for cable and a separate input for labor and material costs for structure. In contrast, the RUS data and buried cable and structure regression equations developed from these data, reflect labor and material costs for buried cable and structure combined.

127. Significantly, the criticisms of our development of the 24-gauge buried copper cable equation, buried structure equation and buried fiber cable equation in this manner ignore the fact that reliable, alternative data for buried cable costs and buried structure costs is not available on the record.[290] Given that the model requires a separate input reflecting labor and material costs for both copper and fiber cable and a separate input reflecting labor and material costs for structure, and that the only reliable data on the record does not separate such costs between cable and structure, we find it necessary to split the regression equation.

128. Contrary to the assertions of the commenters, either express or implied, the steps we took to derive these equations were not arbitrary.[291] We used a single buried structure equation to estimate the cost for buried structure without distinguishing between the equation for buried copper structure and the equation for buried fiber structure because the

[287] *See e.g.*, GTE *Inputs Further Notice* comments at 52-53;

[288] *Inputs Further Notice* at paras. 83, 113. *See also Inputs Further Notice*, Appendix D, sections I.C., III.C.

[289] *Inputs Further Notice* at para. 94. *See also Inputs Further Notice*, Appendix D, section II.C.

[290] Moreover, at least one LEC commenter states that it is not able to separate buried structure costs from total buried plant costs. GTE *Inputs Further Notice* comments at 53. This inability may reflect the fact that under current FCC accounting guidelines these costs are not identified separately.

[291] *See e.g.*, GTE *Inputs Further Notice* comments at 52; BellSouth *Inputs Further Notice* comments, Attachment A at A-16.

model does not distinguish between buried copper structure costs and buried fiber structure costs. We find that this is reasonable because the intercept and the coefficients for the variables that primarily explain the variation in structure costs, i.e., the variables that indicate density zone, the combined soil and rock type, and the presence of a high water table, in the combined regression equation for buried fiber cable and structure are not statistically different from the intercept and the coefficients for these variables in the combined regression equation for 24-gauge buried copper cable and structure.[292] We also find that it is reasonable to develop a separate structure equation from the regression equation for the combined cost of 24-gauge buried copper cable and structure rather than from the regression equation for the combined cost of buried fiber cable and structure because the water and soil and rock type indicator variables in the regression equation for the combined cost of 24-gauge buried copper cable and structure are statistically significant. In contrast, these variables are not statistically significant in the buried fiber cable and structure regression equation.[293] In addition, we note that the number of observations used to estimate the 24-gauge buried copper cable and structure regression equation, 1,131, exceeds the number of observations used to estimate the buried fiber cable and structure regression equation, 707 observations.

129. We note that we included in the separate buried cable equations the variable for cable size and its coefficient reflected in the combined cable and structure regression equations. We find that this is reasonable because the cable size variable and its coefficient explain the variation in cable costs. We also note that we excluded from the separate buried cable equations the independent variables in the combined cable and structure regression equations that indicate density zone, the presence of a high water table, and the soil and rock type. We find that this is reasonable because these variables and their coefficients explain primarily the variation in buried structure costs. Conversely, we excluded from the separate buried structure equation the variable for cable size and its coefficient reflected in the combined 24-gauge buried copper cable and structure regression equation because this variable and its coefficient explain the variation in cable costs.

130. We also included in the separate structure equation the variables and the coefficients for the variables that indicate density zone, the combined soil and rock type, and the presence of a high water table in the combined regression equation for 24-gauge buried copper cable and structure. Again, we find this is reasonable because these independent variables and coefficients primarily explain the variation in structure costs.

[292] That is, the values of the intercept and the coefficients for the variables that indicate density zone, the combined soil and rock type, and the presence of a high water table in the combined regression equation for buried fiber cable and structure lie within the 95 percent confidence interval surrounding the values of the intercept and the coefficients for the respective variables in the combined regression equation for 24-gauge buried copper cable and structure.

[293] Nevertheless, the value of the F-statistic for the regression equation for the combined cost of buried fiber cable and structure, 172.80, indicates that the regression equation is statistically significant.

131. Finally, because the estimated intercepts in the regression equations for the cost of buried cable and structure reflect the fixed cost for both buried cable and structure in density zone one, we included in the separate equations for buried cable an intercept reflecting the fixed cost of cable. Similarly, we included in the equation for buried structure an intercept reflecting the fixed cost of structure in density zone one. Specifically, we allocated an estimate of the portion of the combined fixed cable and structure costs that represents the fixed copper cable costs reflected in the intercept in the 24-gauge buried copper cable and structure cost regression equation to the intercept in the equation for 24-gauge buried copper cable. Correspondingly, we allocated an estimate of the portion of fixed cable and structure cost that represents the fixed costs of buried structure reflected in the intercept in the buried 24-gauge copper cable and structure cost regression equation to the intercept in the equation for structure costs. We also allocated to the intercept in the separate buried fiber cable equation the remaining portion of the fixed costs reflected in the intercept in the combined buried fiber cable and structure regression equation after subtracting from the value of this intercept the estimate for fixed structure costs in density zone 1 in the separate buried structure equation. The sum of the particular values that we adopt for the fixed cable cost in the separate 24-gauge copper cable equation, \$.46, and the fixed structure cost in density zone 1 in the separate structure equation, \$.70, equals the 24 gauge buried copper cable and structure fixed costs reflected in the intercept in the combined copper cable and structure regression equation of \$1.16. The sum of the particular values that we adopt for the fixed cable cost in density zone 1 in the separate fiber cable equation, \$.47, and the fixed structure cost in the separate structure equation of \$.70 equals the buried fiber cable and structure fixed costs reflected in the intercept in the combined fiber cable and structure regression equation, \$1.17. We find that these values are reasonable. We note that \$.46[294] lies between AT&T and MCI's estimate of the fixed cost for a 24-gauge buried copper cable of \$.12[295] and the HAI default value for the installed cost of a 6-pair 24-gauge buried copper cable of \$.63.[296] Moreover, we note that we could have used relatively higher or lower values for the fixed structure and cable costs in the separate structure and cable equations. However, we note that the sum of the fixed costs reflected in the buried structure cost estimates (excluding LEC engineering costs) developed from the separate buried structure equation and the fixed costs

[294] This estimate of the fixed cost for a 24-gauge buried copper cable excludes fixed costs for structure, LEC engineering, and splicing, but includes fixed costs for contractor engineering.

[295] *See* AT&T and MCI *Inputs Further Notice* comments, Appendix A at A-7. The AT&T and MCI estimate of the fixed cost for a 24-gauge buried copper cable excludes fixed costs for structure, splicing, and contractor and LEC engineering.

[296] *See* HAI Model, Release 5.0a, Model Description, Appendix B at 15. A 6-pair 24-gauge buried copper cable is the smallest buried cable for which HAI has a default value. The HAI default value for the installed cost of a 6-pair 24-gauge buried copper cable excludes fixed and variable costs for structure, but includes fixed and variable costs for material, contractor and LEC engineering, and splicing. Fixed cable costs do not vary with cable size. A large percentage of the installed cable cost for a small cable is a fixed cost.

reflected in the buried cable cost estimates (excluding LEC engineering and splicing costs) developed from the separate buried copper or fiber cable equation is not affected by the relative values that we use for the fixed cost in these separate equations.[297]

132. Finally, we note that GTE contends that the proposed equations for buried cable and buried structure are questionable because the buried structure costs would not vary with the presence of water.[298] As discussed below, we have modified the regression equation for buried copper cable and structure by adding the variable that indicates the presence of a high water table. We obtain structure cost estimates used as input values by setting the coefficient for the water indicator variable equal to zero. These structure cost estimates, therefore, assume that a high water table is not present. The model adjusts these estimates to reflect the impact on these costs of a high water table. GTE also claims that the proposed equations are questionable because the costs for buried structure derived from the buried structure equation would not vary with cable size. We reject this contention. GTE has not provided any evidence that demonstrates that buried structure costs vary with cable size. To the contrary, GTE states that it cannot produce such evidence because it is not able to separate actual costs of buried structure from total costs of buried plant.

133. In sum, we find that the regression equations we proposed and tentatively adopted in the *Inputs Further Notice* are an appropriate starting point for estimating cable costs and structure costs for non-rural LECs for purposes of developing inputs for the model, particularly given the absence of more reliable cable and structure cost data from any other source.[299] We find, however, that certain commenters' criticisms of the regression equations we proposed have merit. We make the following adjustments to improve the regression

[297] The sum of the fixed costs reflected in the buried structure cost estimates, including LEC engineering costs, developed from the separate buried structure equation and the fixed costs reflected in the buried copper or fiber cable cost estimates, including LEC engineering and splicing costs, developed from the separate buried cable equation is affected slightly by the relative values used for the fixed cost in these separate equations. The relative values used for these fixed costs affects slightly the sum of these fixed costs because a splicing loading of 9.4 or 4.7 percent is applied to the fixed cost reflected in the separate buried copper or fiber cable cost estimates (excluding LEC engineering and splicing costs), while a loading of 10 percent for LEC engineering is applied to the fixed cost reflected in the separate buried structure cost estimates (excluding LEC engineering costs).

[298] GTE *Inputs Further Notice* comments at 52.

[299] We note that the regression equations in the NRRI Study are a starting point because, as we explained in the *Inputs Further Notice,* and discuss in more detail below, we proposed to modify the regression equations used to estimate cable costs to capture the buying power of the non-rural LECs reflected in the price they pay for cable.

equations consistent with those criticisms.[300]

134. First, we remove the independent variable that indicates whether two or more cables are placed at the same location from the regression equations for 24-gauge aerial copper cable, 24-gauge buried copper cable and structure, aerial fiber cable, and buried fiber cable and structure.[301] As a result, the regression equations we adopt do not have this variable as an independent variable. We do not include this independent variable in any of the cable and structure equations because the model does not use a different cable cost if the outside plant portion of the network it builds requires more than one cable.

135. We also remove from the regression equation for 24-gauge underground copper cable the variable that is the mathematical square of the number of copper cable pairs. We remove this variable because its use results in negative values for the largest cable sizes, as some parties point out.[302] We note that none of the other proposed cable and structure regression equations had this variable as an independent variable.

136. We add the variable that indicates the presence of a high water table to the regression equations for buried copper cable and structure and underground structure costs. With this change, all of the regression equations for structure costs adopted in this Order have this variable as an independent variable.[303] We include this variable in the structure equations because the model applies a cost multiplier to all structure costs when the water table depth is less than the critical water depth. To develop structure cost inputs, we set the value of the water indicator variable equal to zero in the structure regression equations, thereby developing structure costs that assume that there is no water in the geographic area where the structure is installed. The multiplier in the model then adjusts these costs to reflect the impact on these costs of a high water table when it determines that the water table depth is less than the critical water depth.

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[300] We set forth in Appendix B the regression equations that we adopt in this Order. We also set forth in Appendix B the adjustments we make to those equations to reflect the buying power of large LECs, splicing costs, LEC engineering costs, and to separate the buried cable and structure regression equations into separate equations for buried cable and buried structure.

[301] *See* Bell Atlantic *Inputs Further Notice* comments, Attachment C at 25; Ameritech *Inputs Further Notice* comments at 13-14; US West *Inputs Further Notice* comments, Attachment A at 9, 11.

[302] *See e.g.*, Ameritech *Inputs Further Notice* comments at 10-11; GTE *Inputs Further Notice* comments at 30-31; Bell Atlantic *Inputs Further Notice* comments at 25-26; US West *Inputs Further Notice* comments, Attachment A at 9.

[303] *See* Bell Atlantic *Inputs Further Notice* comments, Attachment C at 25-26; Ameritech *Inputs Further Notice* comments at 13; US West *Inputs Further Notice* comments, Attachment A at 9; GTE *Inputs Further Notice* comments at 30-31.