Appendix P
Non-Structural

Fargo-Moorhead Metropolitan Area Flood Risk Management

Final Feasibility Report and Environmental Impact Statement

July 2011

US Army Corps of Engineers ®

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Appendix P

Non-structural

Table of Contents

Part 1: May 2010 Non-structural assessment (75 pages)

Part 2: July 2011 Supplemental non-structural assessment (33 pages)

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PART 1
NONSTRUCTURAL ASSESSMENT
FOR THE
FARGO-MOORHEAD METRO FEASIBILITY STUDY
MAY 2010

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FARGO–MOORHEAD METRO AREA NONSTRUCTURAL REPORT

1.0 Introduction to Nonstructural Assessment

The Corps of Engineers, St Paul District [MVP] is engaged in a feasibility study to reduce flood damages, improve ecosystems, and realize other related water resource opportunities in Fargo, North Dakota and Moorhead, Minnesota. In terms of flooding, the Red River of the North is the major flood threat for the cities with the Wild Rice, Sheyenne, Maple, and Rush Rivers influencing the Fargo area and the Buffalo River influencing the Moorhead area.

MVP completed a report entitled “Fargo-Moorhead Metropolitan Area Reconnaissance Study” in March 2008 and then revised the report in April 2008 (Reference 1). This report concluded that “cost effective engineering solutions to water resource problems in the Fargo-Moorhead Metropolitan Area can be formulated that will result in one or more projects with benefits in excess of project costs”. The report addressed nonstructural measures and stated “Nonstructural measures alone would not meet the overall planning objectives. However, all of these measures should be considered for integration with structural measures to maximize effectiveness of the alternatives”. The Mississippi Valley Division, after its review of the report stated “Nonstructural flood risk management measures should be fully addressed in the feasibility study”. The present direction of the feasibility study is to investigate flood risk reduction opportunities, both nonstructural and structural, that can be used to achieve the planning objectives of reducing flood damages/risk and restoring/improving degraded riverine and riparian habitat.

This appendix contains detailed technical information used in the analysis of existing conditions, in the development of problem solving measures, and in the analysis, evaluation, comparison, screening, and selection of alternative nonstructural plans. The appendix is currently presented as tentatively selected recommendations contained in the main report. This appendix functions as a complete technical document to support the nonstructural analysis portion of the feasibility study process. However, because of the complexity of the plan formulation process used in this planning study, the information contained herein should not be used without parallel consideration and integration of all other appendices, and the main report that summarizes all findings and recommendations.

Nonstructural measures are proven methods and techniques for reducing flood risk and flood damages in floodplains. Thousands and thousands of structures across the nation are subject to reduced risk and damage or no risk and damage due to implementation of nonstructural measures. Besides being very effective for both short and long term flood risk and flood damage reduction, nonstructural measures can be very cost effective when compared to structural measures. A particular advantage of nonstructural measures when compared to structural measures is the ability of nonstructural measures to be sustainable over the long term with minimal costs for operation, maintenance, repair, rehabilitation, and replacement (OMRRR).

Nonstructural measures are obviously very building/structure specific. Each structure is different and may require a different nonstructural measure. In order to achieve this level of specificity, each structure will have to be inspected by a team consisting of a floodplain engineer, structural engineer, cost engineer, civil engineer, and real estate specialist in order to determine, prior to implementation, the specifics relative to each type of measure employed. Because of the nature of this level of investigation, this degree of specificity was not possible within this phase of study.

Nonstructural measures require different implementation as compared to structural measures. Since each structure is owned and occupied by people, agreements must be entered into with each owner.

In order to achieve flood risk/flood damage reduction, structure owners need to participate in any project incorporating nonstructural measures. This can be either voluntary or mandatory depending upon the needs of the project and the desires of the community. Voluntary is always the preferred method of implementation, but could result in a patchwork effect due to some owners refusing to participate in the project.

With implementation of any flood risk/flood damage reduction project, the ability of the project to achieve the objectives must be considered not just for the short term but also for the long term. Nonstructural measures are most advantageous over structural measures especially for the long term if full, unbiased consideration is given to OMRRR costs not just for the economic life of the project which is normally 50 years, but for the ability of the project to provide the desired level of flood risk reduction for as long as the damage center exists which is in perpetuity. Within the context of nonstructural measures, measures which can be implemented in the short term by the Corps of Engineers in partnership with Fargo and Moorhead will be considered. However, measures that may require intermediate terms and long terms for implementation should also be identified at least in concept and incorporated into each community's floodplain management plan for development and implementation as opportunities voluntarily arise or as opportunities are made to happen.

The ability of nonstructural measures to be implemented in very small increments, each increment producing flood risk reduction benefits, and the ability to initiate and close a nonstructural program with relatively minimal costs are important characteristics of this form of flood risk reduction. Also important is the ability to implement measures over intermediate and long periods such that layering of measures, each one providing a higher degree of risk reduction, is possible and given both Federal and non Federal funding constraints probable.

The overall most important objective and result of this study effort for the cities of Fargo and Moorhead is to implement a program of "No Flood Risk." While it is unrealistic to assume that these communities can ever achieve a state of "No Flood Risk" due to their far remoteness from topography that is high enough in elevation above any flood source to be flood free for even the most rare frequency of flood, this should be a goal. The essence of the "No Flood Risk" concept is that flood risk is an integral part of each and every decision within the metro area by all entities ranging from private to public. Each decision should be made to reduce flood risk as much as possible and to move to a "No Flood Risk" community as much as possible.

1.2 Flood Risk Perspective and Nonstructural Measures

Flood risk in the United States continues to increase despite many efforts during the past decades to reduce and eliminate that risk. Flood risk is defined as the product of the frequency of flooding and the consequences of flooding. Early efforts to reduce flood risk were focused on controlling floods by reducing the frequency of flooding with the use of structural alternatives such as dams, levees, channels, and diversions. These structural alternatives modified the characteristics of floods. This concept began to fade in the 1960's as it became apparent that structural means alone could not reliably control nature and contain flooding. The focus then evolved to flood *damage* reduction. The theory with the flood damage reduction focus was in order to reduce flood damage from an economic perspective the focus had to be not only on reducing the frequency of flooding but also the consequences of flooding. The flooding could be made less damaging through modifying the characteristics of floods [structural alternatives] and also modifying the characteristics of development in the floodplain and the behavior of people living within the floodplain [nonstructural alternatives]. Flood damage reduction focused primarily on damages and their effects on the economy. In the past several years; however, the nation has shifted its thinking to overall flood *risk* reduction and *flood risk management*. The nation has recognized that the adverse affects of flooding were manifested comprehensively across many categories including loss of life, rather than simply economic damages. In the flood risk reduction/flood risk management environment, floodplain/flood risk managers realize that to effectively reduce flood risk, all "tools" in the flood risk reduction "tool box" must be used. These "tools" include both structural and nonstructural measures. These measures, when considered in the context of reducing flood risk, become alternatives that can be compared with other alternatives.

The overall purpose of a nonstructural alternative is to reduce flood risk. Nonstructural alternatives reduce flood risk by modifying the characteristics of the buildings and structures that are subject to floods or modifying the behavior of people living in or near floodplains. In general, nonstructural alternatives do not modify the characteristics of floods nor do they induce development in a floodplain that is inconsistent with reducing flood risk. Some nonstructural measures that can be formulated into nonstructural alternatives include removing buildings from floodplains by relocation or acquisition; flood proofing buildings; placing small levees, berms or walls around buildings; implementing flood warning and preparedness activities; and implementing floodplain regulation. The National Flood Insurance Program (NFIP) is considered among nonstructural alternatives since it contains programs to provide minimum standards for floodplain regulation, to provide flood insurance, and to provide flood hazard mitigation. In contrast, structural alternatives reduce flood risk by modifying the characteristics of the flood. Structural alternatives do not modify the characteristics of existing development in the floodplain. Because structural alternatives reduce the frequency of flooding within a particular floodplain, they can affect the behavior of people living in or near the floodplain by allowing them to think that the floodplain is no longer subject to flooding. Because of this, structural alternatives, while they decrease the frequency of flooding, can actually increase flood risk if the consequences of flooding are allowed to increase. This occurs when new development is placed in the floodplain that is inconsistent with reducing flood risk.

Some of the *basic* measures used to develop nonstructural alternatives are as follows:

- Relocate buildings from the floodplain to a flood-free location
- Acquire the floodplain land on which the relocated buildings previously existed and enforce deed restrictions so the land will never be developed in the future for uses that are subject to flood risk
- Acquire floodplain land that is in existing open space used to prevent future development that could be at flood risk
- ”Buy out” buildings within the floodplain, destroy them, and enforce deed restrictions to prevent future development that could be at flood risk
- Elevate buildings above a particular flood elevation.
- Dry flood proof buildings (traditional building waterproofing)
- Wet flood proof buildings (retrofitting existing buildings below a design flood elevation with water resistant materials and allowing flood water to easily flow into and out of the building)
- Install small levees, berms, and walls around one building or a few buildings that are in close proximity to one another. Such levees, berms, and walls are never accredited for the National Flood Insurance Program
- Install flood warning systems
- Develop and implement flood preparedness plans
- Floodplain regulation and floodplain management
- Restoring natural and beneficial floodplain functions
- Communication and education programs aimed at achieving no flood risk
- The National Flood Insurance Program
- Watershed/floodplain land use planning
- Transfer of development rights and purchase of development rights
- Development impact fees
- Land development redirection
- Land taxation policies and special assessments

Each of these general categories of nonstructural measures can be applied as single measures or can be applied in combination with one another or with structural measures to reduce or eliminate flood risk. The range of benefits, costs, and residual damages associated with the application of each measure is broad. The extent and severity of social and economic impacts associated with the various measures can be likewise broad and must be identified for any plan. Depending upon the nonstructural measures selected for application and the relative percentage of each applied to the metro area, the future land use pattern of the area could look considerably different in specific areas of the metro and the excitement, aesthetics, and livability experience of the metro area greatly enhanced while flood risk is reduced.

In terms of flood risk, it is unfortunate that floodplain areas are so attractive to commercial, residential, and industrial developers. The consequences associated with locating damageable property and people within such areas can be extreme to not only property owners and floodplain occupants but to taxpayers at all levels who have, over the decades, largely evolved to “foot the bill” for flood response, recovery, and rebuild when a flood source decides to reoccupy its traditional floodplain.. Within the context of this study, an objective is to identify strategies and measures that can be used in tandem to both discourage development in high risk areas and to encourage development in areas of low and no risk. Some strategies and measures may be more appropriate for Federal action while others will be more attuned to local regulatory action and administration. In either case, these measures must be effective, socially acceptable, environmentally suitable, and mindful of the existing neighborhood and community social and economic systems within which they would be implemented. It is the intent of this appendix to identify such nonstructural measures.

1.3 Floodplain and Flood Risk Characteristics

Fargo and Moorhead are both exposed to flood risk from the Red River of the North. While other flood sources are located in the area as mentioned above, the Red River of the North remains as the primary flood source of concern. While some permanent levees have been constructed along the Red River and some upstream flood storage exists in the Red River Basin upstream from the metro area, flood water surface elevations from the 100-year and larger floods in the metro area are excessive. As stated earlier, the floodplains in both Fargo and Moorhead are relatively flat. An examination of a flooded area map for the metro area shows the floodplain for the 500-year flood to cover almost all of Fargo. As stated earlier, the topography of Moorhead, while relatively flat, does provide greater elevation relative to the Red River than does Fargo. For this reason, a much larger percentage of Moorhead than Fargo is located above the 500-year flood. Depths of flooding for 100-year and 500-year floods can vary from several feet to zero depending on location.

The source of the most major historic floods from the Red River is spring snowmelt, with summer rainfall events also causing flood problems. Because of the characteristics of the Red River Basin, flood warning is generally quite ample to enable human intervention to reduce flood damages. Because of the basin characteristics and the characteristics of the Red River within the metro area, actual flood duration can last from days up to weeks.

The floodplain within Fargo and Moorhead consists of basically the entire spectrum of development—residential, commercial, industrial, and governmental. Basements are prevalent. Almost all residential structures have basements, with many being a form of “walk out”. Basements also exist in some of the other building types. Age of development is also across the entire spectrum from new to old.

The floodplain for purposes of this appendix is considered to be the entire floodplain from the Red River. This is not just the 100-year floodplain that the National Flood

Insurance Program specifically relates to but rather the entire floodplain that is subject to flooding from any flood, regardless of how infrequent that flood is. With that definition of floodplain, no part of the present Fargo Metro Area is located out of this floodplain. Looking at the Moorhead Metro Area, the same is probably true with the caveat that there does exist locations within Moorhead that are on higher ground, but probably still located within the above definition of floodplain. What this paragraph discussion is really saying is from the perspective of reducing flood risk in the Fargo-Moorhead Metro Area in its totality, further floodplain development within this total Metro Area would appear now to make most sense to be in the eastern portion of Moorhead rather than within Fargo.

1.4 Executive Order 11988

This executive order [EO] was issued by President Jimmy Carter on 24 May 1977 and is entitled “Floodplain Management”. In issuing the EO the President stated “in order to avoid to the extent possible the long and short term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative, it is hereby ordered that each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities…”. The nonstructural analysis was done in complete compliance with the EO meaning that any nonstructural measures that are incorporated into alternatives recommended for implementation support the vision of the EO.

1.5 Critical Facilities

Structures/facilities exist in the metro area which should never be flooded. These are called critical facilities in terms of Executive Order 11988 [EO]. They are essential during a flood to provide human safety, health, and welfare. Facilities that could, if flooded, add to the severity of the disaster such as petroleum terminals, waste water treatment plants, toxic material storage sites, are considered critical. Critical facilities are also generally those services required during the flood such as police and fire protection, emergency operations, people evacuation sites, and medical care. Facilities that house elderly people that require extensive evacuation time would also be considered critical. Each critical facility within the guidelines of the EO should be located at a flood free site. If this is not possible or practicable, the facility should be located external to the 500-year floodplain. If this is not possible or practicable, the facility must be, at a minimum, protected to the extent that it can function as intended during all floods up to and equal to a 500-year event.

Within the nonstructural analysis, all such facilities meeting the critical facility criteria discussed above were treated with nonstructural measures to meet the above objectives for critical facilities. If they were located in the 500-year floodplain, they were considered for relocation if the 500-year flood depth was greater than 9 feet. For flood depths less than 9 feet, other nonstructural measures were considered with the assumption that the facility could continue to function as intended during the flood with implementation of those nonstructural measures.

1.6 Nonstructural Flood Risk Reduction

Two planning objectives exist for this assessment. They are 1) reducing flood damages and 2) restoring or improving ecosystems. Two planning constraints exist. They are 1) avoiding increasing peak Red River flood stages and 2) complying with the Boundary Waters Treaty of 1909 and other pertinent international agreements. Both the planning objectives and the planning constraints can be accommodated with the use of a combination of nonstructural measures.

1.7 Nonstructural Measures Description

The following nonstructural measures were investigated to reduce flood risk within the Metropolitan Area:

<u>1.7.1 Relocation of Structures</u>. This measure requires physically moving the structure as part of the project and buying the land upon which the structure is located. It makes most sense when structures can be relocated from a high flood hazard area to an area that is located completely out of the floodplain. As discussed above, this is not possible within Fargo and may not be possible within Moorhead. Therefore, any structure relocation would consist of moving the structure from an area of high flood hazard to an area of lower flood hazard and then using the nonstructural measure of elevation to achieve the desired level of flood risk reduction within the metro area. Development of relocation sites where structures could be moved to achieve the planning objectives and retain such aspects as community tax base, neighborhood cohesion, can be part of any relocation project. This measure is applicable anywhere in the metro area.

<u>1.7.2 Buyout and Demolition of the Structure</u>. This measure consists of buying the structure and the land as part of the project. The structure is either demolished or the structure is sold to others and relocated to a location external to the floodplain. Development sites, if needed, can be part of the project in order to have locations where displaced people can build new homes within the metro area. This measure is applicable anywhere in the metro area.

<u>1.7.3 Elevation of Structures</u>. This measure requires lifting the entire structure or the habitable area to be above a particular flood event. In the metro area, probably the most acceptable elevation measure would be on extended foundation walls. Since most all of the structures to elevate have basements under them, the concept would be to basically elevate the basement out of the ground. Then depending on the design flood elevation, the elevated basement could be fully developed if the basement floor was located above the Flood Insurance Rate Map [FIRM] base flood elevation [BFE] or the design flood elevation whichever is higher, could be kept undeveloped and wet flood proofed in the regard of equalizing hydrostatic force, or could be developed but with wet flood proofing concepts in more totality. If the basement had been fully developed pre elevation and could not be developed post elevation, compensation of the basement space would be in order to the owner. This measure is applicable anywhere in the metro area unless the

required elevation is greater than a maximum of 12 feet above the adjacent grade. Velocity and hydrodynamic force would also have to be considered.

1.7.4 Removal of Basement. This measure consists of filling in the existing basement without elevating the remainder of the structure. This would occur if the structure first floor was located above the BFE or above the design elevation whichever is higher. With this measure, placing an addition on to the side of the structure as part of the project could occur to compensate for the lost basement space to the owner. If the addition could not be done because of limited space within the lot or because the owner did not want it, compensation for the lost basement space would be in order to the owner. This measure would only be applicable where the design flood depth is relatively small [first floor already above the design depth]. Hydrodynamic forces would also be a consideration.

1.7.5 Dry Flood Proofing. This measure basically consists of waterproofing the structure. This can be done to residential homes as well as all other types. This measure achieves flood risk reduction but it is not recognized by the NFIP for any flood insurance premium rate reduction if applied to residential. Based upon NFPC sponsored tests at ERDC, a “conventional” built structure can generally only be dry flood proofed up to 3 feet on the walls. A structural analysis of the wall strength would be required if it was desired to achieve higher protection. A sump pump for sure and perhaps French drain system is installed as part of the project. Closure panels are used at openings. This concept does not work with basements nor does it work with crawl spaces in the metro area due to the long duration of flood. This measure will work in the metro area if design flood depths are generally less than three feet and on an appropriate structure as discussed. Hydrodynamic forces would also be a consideration. For buildings with basements and/or crawlspaces, the only way that dry flood proofing could be considered to work is for the first floor to be made impermeable to the passage of floodwater.

1.7.6 Wet Flood Proofing. This measure is applicable as either a stand alone measure or as a measure combined with other measures such as elevation which was discussed above. As a stand alone measure, all construction materials and finishing materials need to be of water resistant material. All utilities must be elevated above the design flood elevation. Because of these requirements, wet flood proofing of finished residential structures is generally not recommended. Wet flood proofing is quite applicable to commercial and industrial structures when combined with a flood warning, flood preparedness, flood response plan. This measure is generally not applicable to large flood depths and high velocity flows.

1.7.7 Berms, Levees, and Floodwalls. This measure is applicable to locations within the metro area. As nonstructural measures, berms, levees, and walls should be constructed to no higher than 6 feet above grade and are not certifiable for the NFIP, meaning that flood insurance and floodplain management requirements of the NFIP are still applicable in the protected area. These nonstructural measures are intended to reduce the frequency of flooding but not eliminate floodplain management and flood insurance requirements. These measures can be used for all types of structures in the metro area. They can be placed around a single structure or a small group of structures. With application of these measures to be nonstructural, they cannot raise the water surface elevation of the 100-year flood by any more than 0.00 feet.

1.7.9 Flood Warning, Preparedness, Evacuation Plans and Pertinent Equipment Installation. These measures are applicable to the metro area. All of the above nonstructural measures with the exception of buyout and of relocation to a completely flood free site require the development and implementation of flood warning/preparedness planning. The development of such plans and the installation of pertinent equipment such as data gathering devices (rain gages and stream gages) and data processing equipment (computer hardware and software) can be part of the project.

1.7.10 Land Acquisition. Land acquisition can be in either the form of fee title or permanent easement with fee title the preference. Land use after acquisition is open space use via deed restriction that prohibits any type of development that can sustain flood damages or restrict flood flows. Land acquired as part of a nonstructural project can be converted to a new use such as ecosystem restoration and/or recreation that is open space based such as trails, canoe access, etc. Conversion of previously developed land to open space means that infrastructure no longer needed such as utilities, streets, sidewalks, etc can be removed as part of the project. The conversion to new use [ecosystem restoration and/or recreation] can also be part of the project. By incorporating " new uses of the permanently evacuated floodplains" into the nonstructural flood risk reduction project, economic feasibility of the buyout or relocation projects is enhanced due to transfer of some flood risk reduction costs to ecosystem restoration and by adding benefits [and costs] of recreation. This will be determined by use of the "Separable Costs/Remaining Benefits" guidance. Other Federal agencies such as the NRCS have permanent easement programs to restore wetlands in "evacuated" floodplains that could be used in a collaborative mode with a Corps nonstructural program.

1.7.11 Floodplain Management Plans. A floodplain management plan (FPMP) is required of the Corps non-Federal project sponsor. The intent of a FPMP is to maintain the integrity of the Corps partnered project from having the frequency of flood risk reduction provided by the project from being diminished. This is a non-Federal sponsor required activity, but if done during the feasibility phase of study, can be cost-shared on the same basis as the feasibility study. This makes sense for the local sponsor from not only the cost-share perspective, but also from the holistic flood risk reduction perspective. This latter perspective makes sense for the Corps as well. By integrating the FPMP with the feasibility study, both the FPMP and the ultimate project are bettered. It is recommended that the FPMP be prepared within this feasibility study.

1.7.12 Vertical Construction for Residential Occupancy. This nonstructural concept refers to condominium type habitation, where people live within floodplains but they live in apartment type buildings where the at-grade floor is reserved for open space type uses such as auto parking. The remaining floors of the building which are all located above even the most infrequent flood are where the residential construction occurs. This vertical construction is proposed for consideration within the metro area for the simple reason that, especially in Fargo, no area within a close proximity to Fargo is high enough in elevation above the Red River floodplain to be totally above the floodplain for flood free construction of residential structures. This may be the same for Moorhead. This concept to change residential construction from single family home to vertical condominium will probably face tough political/social criticism. However, it merits consideration if the metro area is to, in the long term, achieve a No Flood Risk status.

<u>1.7.13 Communication and Education Aimed at Achieving No Flood Risk</u>. Communication and education concerning flood risk is extremely vital and must be done on a continuous basis. People who have received the education tend to forget and new people coming into the metro area need to be educated quickly about the flood risk that exists in the metro area. Far too often communities make an effort to “disguise” the true flood risk from people because the local economic engine of property tax base and new development overrides any thoughts on flood risk and safety from floods. This position is, in a de facto sense, supported by State and Federal government because of the availability of post flood funding for flood response, flood recovery, and flood rebuild from such government agencies via taxpayers. Any communication and education programs must cover all entities within the metro area. At a bare minimum, annual emergency drills and testing of flood warning equipment must occur. This must include not only government responsible functions but also individual responsible functions. The owner of each structure within a floodplain should have a flood emergency/response plan that they practice each year. The essence of any communication and education program within the metro area should focus on moving the communities to a No Flood Risk environment to the maximum extent possible by instilling in all entities of the community from individuals to business owners to developers to government officials the importance of asking the following question in any decision process: “What will this decision do in regard to moving my property or my community toward no flood risk?”

<u>1.7.14 Floodplain Regulation and Floodplain Management.</u> Floodplain regulation and floodplain management have proven time and again to be very effective tools in reducing flood risk and flood damage. The basic principles of these tools are based nationally in the NFIP which requires minimum standards of floodplain management and floodplain regulation for those communities that participate in the NFIP. Both Fargo and Moorhead participate in the NFIP. These minimum standards of the NFIP have been shown to be overall inadequate to reduce flood risk and flood damage. This is verified by the fact that the NFIP has been in existence since 1968 and that flood risk and flood damage in the nation has continued to increase over the four decades since the NFIP began with no end to increasing flood risk in sight. This does not mean that the concept of floodplain management and floodplain regulation are not valid. It simply means that the standards are too low and building continues to be done in areas that are too hazardous and in areas that are too low. Both Fargo and Moorhead have standards that are in excess of the minimum standards of the NFIP. This is good. However, from development patterns that currently exist, it shows that these standards should also be enhanced to provide greater consideration of eliminating all flood risk from the metro area.

1.7.15 Restoring Natural and Beneficial Floodplain Functions. As discussed earlier, the nation has employed the concepts of flood control, flood damage reduction, and now flood risk reduction in order to satisfy the desire to gain economic use of floodplains and to also minimize economic damages due to floods. Within the Principles and Guidelines which guide Federal involvement in water resources issues, four accounts presently exist. They are national economic development, regional economic development, other social effects, and environmental quality. Among these four accounts, national economic development has received the most attention in terms of achievement with any water resources projects. The other accounts, while open for consideration, are less emphasized in the decision making process. Within the environmental quality account is where the traditional emphasis was on "restoring natural and beneficial functions" of floodplains. Over the decades of trying to reduce flood damages via water resources projects, it has become increasingly clear and important to include opportunities to enhance, protect, and preserve the environment. The natural and beneficial functions of floodplains are numerous but the ability of a "natural" floodplain to reduce flood damages has not been emphasized nearly to the degree it should. As a nonstructural measure to reduce flood risk, undeveloped floodplains [whether natural or manmade non development] not only reduce flood risk because non damageable property is located in a floodplain, but also reduce downstream flood stages by providing natural floodplain storage for flood water.

1.7.16 National Flood Insurance Program (NFIP). The NFIP is a nonstructural measure. The NFIP contains 3 basic parts; flood insurance, flood mitigation, and floodplain regulation. In terms of reducing flood risk, only flood mitigation and floodplain regulation have a direct impact in theory. In regard to the flood insurance part of the NFIP, flood insurance simply allows spreading the flood risk across multiple properties as does any insurance program. It does not reduce flood risk, it shares flood risk. In fact, the ability of property owners to purchase flood insurance in hazardous areas has overall increased flood risk because property owners with flood insurance are much more willing to accept the risk of hazardous floodplain development since their risk is absorbed by flood insurance that within the NFIP, is rated too low for the insured flood risk. In terms of the NFIP as a nonstructural measure to truly reduce flood risk, the flood mitigation and floodplain regulation parts of the NFIP are those measures. Five mitigation programs exist within the NFIP. They are hazard mitigation grant program, pre disaster mitigation grant program, flood mitigation assistance program, repetitive loss program, and severe repetitive loss program. Within the floodplain regulation part of the NFIP, this serves as a nonstructural mitigation measure indirectly through adoption of minimum floodplain management standards by communities participating in the NFIP. While theoretically these minimum floodplain management standards are good, in reality the focus on the 100 year flood as the de facto floodplain limit has actually promoted development and increased flood risk within those floodplains occupied by floods with frequency of occurrence less than that of the 100 year. The NFIP is discussed in this appendix as a nonstructural measure because the overall intent of the program is to reduce flood risk. However, as briefly pointed out above, some aspects of the program have actually resulted in and continue to result in increased flood risk. While concepts to implement at the national level that would enable the NFIP to be much more friendly to reducing flood risk could be offered within this appendix, that is beyond the influence of this appendix and of these communities. However, while the communities of Fargo and Moorhead cannot change the national minimum NFIP standards, they can change local standards that achieve higher levels of flood risk reduction. Some of those possible higher standards are:

- replace elevation requirements based on the 100 year to the 500 year
- implement a zero rise floodway
- adopt cumulative damages as the trigger for substantial damage determination

1.7.17 Transfer of Development Rights and Purchase of Development Rights. This concept is based on land owners rights to develop property that can be separated from other land rights and traded within a market like system. In general, any land use controls that are specific to a property and significantly decrease the market value of property or remove an opportunity to receive some economic value or use from the property have been considered a taking. In order to facilitate moving development rights from one property that is most flood prone to another property that is much less flood prone or, ideally, flood free, the concept of transfer of development (TDR) rights developed. Another variation of this concept of removing development rights from a flood prone property is called purchase of development (PDR) rights. In either case, removing development rights from a particular property is voluntary so a takings issue does not exist. Within TDR, the development rights are purchased and sold in a market setting. Under TDR, the cost to a public entity is minimal generally being limited only to administrative type costs. PDR is similar in removing development rights from a flood prone property, but it requires the public entity to purchase the development rights and to not sell the rights. PDR is quite similar to easement programs where specific property rights are purchased by a public entity, the landowner retains title to the property with specified rights, property taxes can be lowered to reflect the loss of rights, and the public entity gains specific use rights to the property as negotiated. Both of these measures reduce flood risk by nonstructural methods and should be considered as tools to reduce flood risk both short term and long term.

1.7.18 Development Impact Fees. Development Impact Fees are accessed by public entities in return for permits to develop property. Within floodplains, such fees could be used to mitigate any impacts that such a development would have on other property in terms of flood risk increase. They could also be used to pay for any future flood related costs to property located within the development area. This could apply to both public property such as streets, infrastructure in or serving the developed area and to private property such as homes and businesses that are located in the developed area. This concept can be implemented as a nonstructural measure to reduce flood risk.

1.7.19 Land Development Redirection. Directing future land use away from high flood hazard areas is the basis of this concept. This can be done via several concepts such as those already discussed above and it can be done via specific actions that redirect growth and development into less hazardous areas. These later actions are not only land acquisition but also infrastructure development in areas of less and ideally no flood hazard. Within the metro area, this concept really means redirecting growth into areas of low or no flood hazard regardless of where the growth occurs in the metro area. If such redirected growth remains with areas subject to flood hazard but at a reduced level relative to other areas, implementation of the basic nonstructural measure of elevation must be incorporated into the redirection rather than simply build at grade as if a flood hazard did not exist. Then rely on implementation of a structural measure such as a levee to further reduce the flood risk by decreasing the frequency of flooding. As discussed earlier, redirecting growth while attempting to reduce flood risk with a levee will ultimately result in increased flood risk as the consequences of floodplain occupation are increased.

1.7.20 Land Taxation Policies and Special Assessments. This concept works by requiring higher taxes and special assessments on property that is at high flood risk than property that is of low or no flood risk. This concept makes sense because of higher costs incurred by communities to maintain services, respond to floods, etc, etc within such areas. This type of economic disincentive would discourage development and redevelopment in high flood hazard areas. The essence of these nonstructural measures is to reflect the high flood hazard in higher costs to those who choose to develop in, own property in, and live in such areas that require a larger burden on communities. It is basically letting the cost to the property be reflective of the flood hazard.

1.8 Criteria for Implementation of Nonstructural Measures

Implementation of nonstructural measures can be quite specific in terms of there application to structures or land or they can be quite non specific with quite broad application. Of the above discussed measures, those that are quite structure/land specific are as follows:

- Relocation of structures
- Buyout and demolition of structures
- Elevation of structures
- Removal of basement
- Dry flood proofing
- Wet flood proofing
- Berms, levees, and flood walls
- Land acquisition

Of those measures discussed, those that are quite broad in terms of application are as follows:

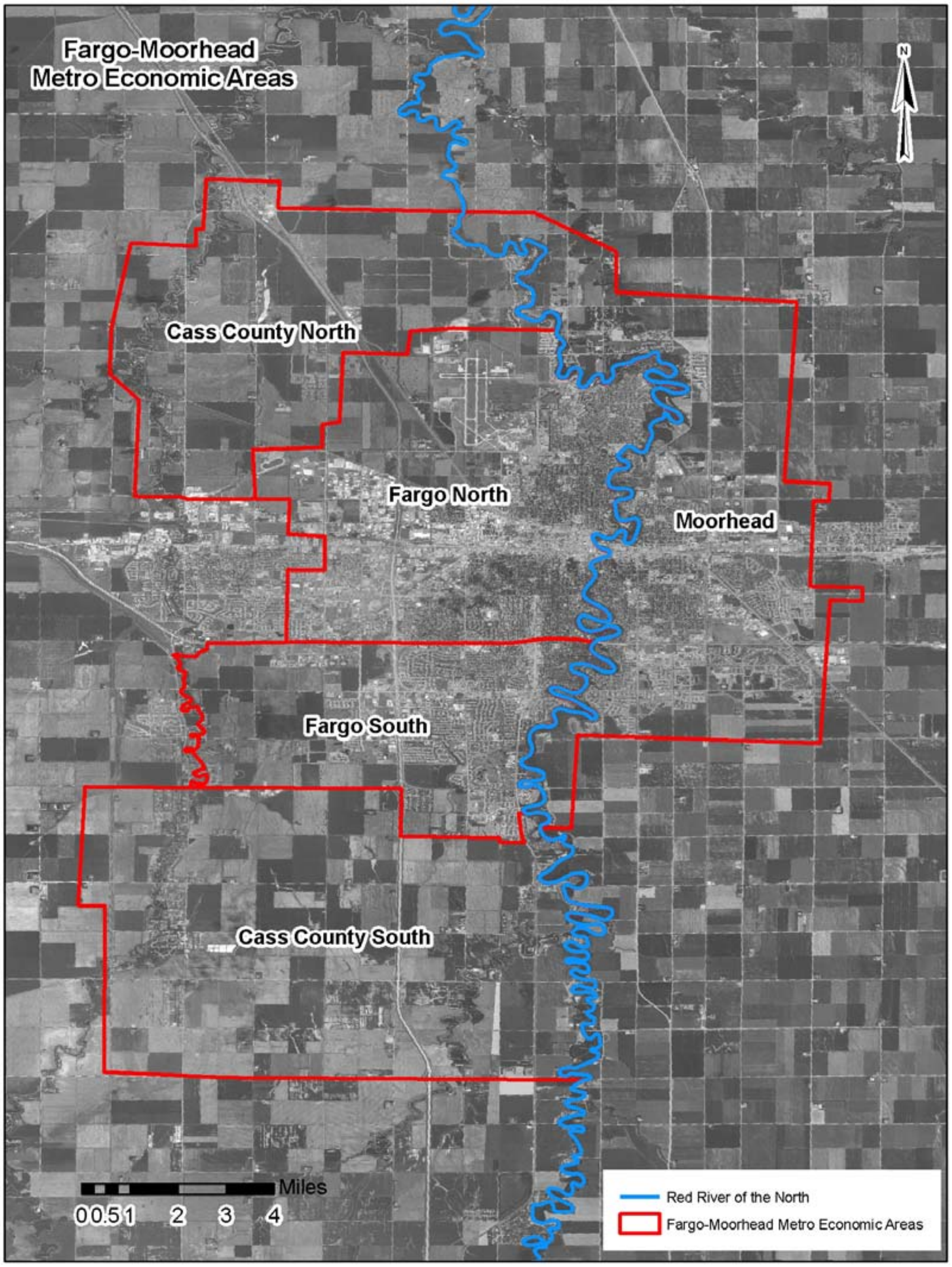
- Flood warning, preparedness, evacuation plans and pertinent equipment installation
- Floodplain management plans
- Vertical construction for residential occupancy
- Communication and education aimed at achieving no flood risk
- Floodplain regulation and floodplain management
- Restoring natural and beneficial floodplain functions
- National Flood Insurance Program
- Transfer of development rights and purchase of development rights
- Development impact fees
- Land development redirection

- Land taxation policies and special assessments

The following paragraphs will address each structure/land specific measure with further specificity in terms of application to the Fargo-Moorhead Metro Area. These paragraphs will also discuss any criteria developed by the NFPC in order to consider the application of each measure.

The metro area contains multiple structures. These structures are generally residential, commercial, industrial, and public. The economic subunit and the data contained within are exactly as provided to the NFPC by St. Paul District. The location of the economic subunits is presented in Figure 1. For a nonstructural analysis, each structure must be examined for purposes of what type of nonstructural measure is most appropriate for that particular structure given what it is, where it is located within the floodplain, what the flood characteristics are, etc. The task within this phase of study for the NFPC team was to develop a "stand alone" nonstructural alternative consisting of 100% nonstructural measures that could be used to provide specific flood risk reduction to all specific structures.

Figure 1
Economic Subunit Location



This was a daunting task considering the time constraint, the readiness of data from St. Paul District, and the specificity of the data relative to each and every structure. In terms of specificity of data, data was not available that was needed in order to correctly and thoroughly analyze each structure and apply a nonstructural measure. Some examples of this lack of specific data are presence of basements, condition of basements, elevation of basement floor, elevation of first floor, number of doors and windows in each building, elevation of the doors and windows, composition of the floor separating the basement from the first floor and number of openings in this floor, number of finished basements, type of basement finish, size of structure relative to the size of lot, materials the buildings are made of, etc, etc, etc. With this many unknowns, the NFPC team had to make many assumptions in order to accomplish the task of developing “stand alone” nonstructural alternatives with cost estimate and ultimate benefits. Following are some of those assumptions:

- Gas stations, drug store, grocery stores, bakeries, restaurants, bowling alleys, warehouses, theaters, hotels and motels, auto dealerships, industrial buildings, processing plants, etc did not have basements
- All other structures/buildings had basements
- All structure/building footings were 7 feet below ground
- All buildings with basements had the basement floor 6 feet below ground elevation
- All nonstructural flood walls were assumed attached to the building and the length determined by building perimeter
- All basement fills are done up to 30 inches below the first floor
- Some nonresidential structures having basements were assumed to be able to waterproof the floor/ceiling between the first floor and the basement to make it impenetrable for flood water
- The value of a finished basement and of a non finished basement was assumed to be 60% and 15% respectively of the value of the finished non basement area on a square foot basis

Nonstructural measure applicability is determined by the flood, building, and site characteristics making each application of nonstructural measures unique to that structure. Table 1 contains the criteria developed by the NFPC to apply nonstructural measures to each structure based on flood depth at the structure, the type of structure, and whether or not a basement existed.

The NFPC decided that the frequency of flood to be mitigated by nonstructural measures should be the same as that used for structural measures. For purposes of this phase of study three floods were considered, the 100-year, 200-year, and 500-year. If the structural analysis involves flood frequencies less than 100-year, the application of most all nonstructural measures that do not relocate or buyout the structure require the minimum standard to be the 100-year. This is because of the substantial improvement requirement of the NFIP that basically states if a structure is improved more than 50% of its pre-improvement value; it must be brought into full compliance with the NFIP which means a 100-year level of flood risk reduction.

Table 1
NFPC Flood Damage Reduction Matrix

US Army Corps Of Engineers

National Nonstructural/ Flood Proofing Committee

US Army Corps of Engineers
Nonstructural/ Flood Proofing
National Nonstructural/Flood Proofng Committee

	FLOOD DAMAGE REDUCTION MATRIX	Elevation on Foundation Walls	Elevation on Piers	Elevation on Posts or Columns	Elevation on Piles	Elevation on Fill	Relocation	Buyout/ Acquisition	Floodwalls and Levees	Floodwalls and Levees with Closures	Dry Flood Proofing	Wet Flood Proofing	Flood Warning Preparedness	NFIP: Flood Plain Regulation	NFIP: Flood Insurance	NFIP: Flood Mitigation [1]	Channel	Levee/Wall	Dams	Diversions
	FLOOD DAMAGE REDUCTION MEASURES	NON-STRUCTURAL MITIGATION MEASURES															STRUCTURAL MITIGATON MEASURES			
Flooding Characteristics	**Flood Depth**																			
	Shallow (<3 ft)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Moderate (3 to 6 ft)	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Deep (greater than 6 ft)	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Flood Velocity																			
	Slow (less than 3 fps)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Moderate (3 to 5 fps)	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y
	Fast (greater than 5 fps)	N	N	N	Y	N	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y
	Flash Flooding																			
	Yes (less than 1 hour)	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y
	No	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Ice and Debris Flow																			
	Yes	N	N	N	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y
	No	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Site Characteristics	**Site Location**																			
	Coastal Flood Plain																			
	Beach Front	N	N	N	Y	N	Y	Y	N	N	N	N	Y	Y	Y	Y	N	[2]	N	N
	Interior (Low Velocity)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N
	Riverine Flood Plain	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Soil Type																			
	Permeable	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Impermeable	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Building Characteristics	**Structure Foundation**																			
	Slab on Grade	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Crawl Space	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Basement	Y	N	N	N	N	Y	Y	Y	Y	N	Y	Y	y	Y	Y	Y	Y	Y	Y
	Structure Construction																			
	Concrete or Masonry	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Metal	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Wood	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Structure Condition																			
	Excellent to Good	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Fair to Poor	N	N	N	N	N	N	Y	Y	Y	N	N	Y	Y	Y	[3]	Y	Y	Y	Y
NED/NER/Recreation/Social Characteristics	**Economic**																			
	Structure Protected	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	[5]	N	Y	Y	Y	Y	Y
	Cost to Implement	M	M	M	M	M	H	H	M	M	L	L	L	L	L	H/M	H	H	H	H
	Potential Flood Insurance Cost Reduction (Residential)	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	-	Y	Y	Y	Y	Y
	Potential Flood Insurance Cost Reduction (Commercial)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	-	Y	Y	Y	Y	Y
	Potential Adverse Flooding Impact on Other Property	N	N	N	N	Y	N	N	Y	Y	N	N	N	Y	N	N	Y	Y	Y	Y
	Reduction in Admin Costs of NFIP	N	N	N	N	Y	Y	Y	N	N	N	N	N	[6]	-	[3]	[7]	[7]	[7]	[7]
	Reduction in Costs of Disaster Relief	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Reduction in Emergency Costs	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	[3]	Y	Y	Y	Y
	Reduction in Damage to Public Infrastructure	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	[3]	Y	Y	Y	Y
	Potential for Catastrophic Damages if Design Elevation Exceeded	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	Y	Y	N
	Promotes Flood Plain Development	N	N	N	N	N	N	N	N	N	N	N	N	N	[8]	N	Y	Y	Y	Y
	Environmental																			
	Ecosystem Restoration Possible	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
	Potential Adverse Environmental Impact	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y
	Recreation																			
	Recreation Potential	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	[3]	N	N	Y	N
	Social																			
	Community Remains Intact	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	[4]	Y	Y	Y	Y
	Population Protected	N	N	N	N	N	Y	Y	N	N	N	N	Y	N	N	[3]	Y	Y	Y	Y
	Potential Structure Marketability Increase	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	[5]	N	Y	Y	Y	Y	Y

[1] NFIP Flood Mitigation may vary but it is usually buyout/acquisitic
[2] Not generally recommended
[3] Buyout/acquisition only
[4] Elevation only
[5] Post FIRM construction only
[6] Post FIRM structures elevation on fill
[7] Yes, if project provides 100 year or greater protection
[8] Yes, if in flood plains less frequent than the 100-year

Y-Yes
N-No
L-Low
M-Medium
H-High

May 2007

The US Army Corps of Engineers National Nonstructural/Flood Proofing Committee [NFPC] is available to assist in any aspect of formulating and implementing nonstructural flood damage reduction measures and realizing the opportunities that exist with nonstructural.

For more information, please contact the NFPC Chairman, Mr. Joe Remondini at 918-669-7198 / e-mail joseph.remondini@usace.army.mil or contact the NFPC website at https://www.nwo.usace.army.mil/nfpc/.

Basements are an integral part of living in the Fargo-Moorhead Metro Area as can be seen by the large numbers of structures having basements. While this type of space under a building may make sense from a structure economic perspective, it does not make sense from the perspective of trying to make structures flood safe during flood periods. While the NFPC fully realizes the NFIP accepted flood proofed basement concept employed on some basements in the metro area, the NFPC does not advocate such construction techniques in flood prone areas in the future because of the vulnerability of structures with basements to floods that can exceed the design level of the flood proofed basement.

1.8.1 Relocation of structures. This measure was used for structures that were in floodplains where flood water was greater than 9 feet deep on structures that were considered "critical" as defined in this appendix. While no critical facilities should be located anywhere in a 500 year or more frequent floodplain this is not an option in Fargo or Moorhead due to the lack of "flood free" sites. For such critical facilities where relocation is recommended, the method of relocation is to buyout the structure and land, demolish the structure, and build a new facility at a flood free location or, if in a floodplain, to build the facility to be able to function during a flood with no flood damages to the building or contents.

1.8.2 Buyout and demolition of structures. This measure was recommended for all structures to be removed from the floodplain. With this measure, those property owners would be compensated for the property and would be able to move to any part of the metro area that is not subject to a flood of any greater frequency than the flood that this project is providing flood risk reduction for. Costs for this measure were provided by MVP. This measure was used throughout the metro area for all areas in the NFIP floodway, within all areas 450 feet of the centerline of the Red River, and within all areas that are in defined peninsulas within the meander belt of the Red River whichever is greater in width. It was also required for every structure located anywhere in the metro area that had a design flood depth greater than 9 feet and it was evaluated for cost effective comparison with other nonstructural measures for all depths greater than 6 feet.

1.8.3 Elevation of structures. This measure was considered for all residential structures and for all depths up to 12 feet for residential. It was not considered for nonresidential but for a few exceptions such as building types considered to generally be small. Elevation was not considered viable for nonresidential because of the assumed size of holistic nonresidential buildings.

1.8.4 Removal of basements This measure was considered for all buildings that had basements and had flood depths greater than 6 feet on the grade adjacent to the structure. With filling the basement, the lost space was compensated for by payment or by adding on to the side of the structure if the first floor of the structure was above the design flood elevation.

1.8.5 Dry flood proofing. This measure was considered for all structures that did not have basements and that did not have design flood depths greater than 3 feet above the first floor. This measure was considered for some nonresidential structures with basements assuming the basement could be filled to prevent future use and assuming that the floor/ceiling between the first floor and the basement could be completely sealed and made impenetrable by flood water. Dry flood proofing for these applications does not have any structural steel to provide structural strength to resist hydrostatic force. The resistance to hydrostatic force is provided by the building itself. The dry flood proofing simply waterproofs the building.

1.8.6 Wet flood proofing. Wet flood proofing was not used for any residential structures unless elevation was used to elevate the first floor and the lower, unfinished area was wet flood proofed. Wet flood proofing was considered for cost effectiveness for some nonresidential structures that did not have basements and that had design flood depths less than 6 feet.

1.8.7 Berms, levees, and flood walls. No berms or levees were considered in this analysis for any structures. Flood walls were considered for cost effectiveness in many instances involving nonresidential buildings. Flood walls were not considered for any application where the above adjacent grade design flood depth was greater than 9 feet. Flood walls were considered for structures without basements having design flood depths greater than 3 feet. Flood walls were considered for cost effectiveness for nonresidential structures having basements where basements were filled, the basement ceiling/first floor was made impenetrable to flood water, and the flood depth on the first floor was greater than 3 feet. Floodwalls were also considered for nonresidential structures having basements where the basement was not filled and the flood wall was built to tie into the basement floor and extend up above the design flood depth. All flood walls were assumed to be attached to the structure.

1.8.8 Land acquisition. All relocations and buyouts that involved land acquisition also have incorporated the concept of "new uses of the evacuated floodplain" such as recreation and ecosystem restoration. Costs and benefits related to these uses were determined and the impact of those new uses integrated into the BCR of the nonstructural measures of relocation, buyout, and land acquisition.

1.8.9 Voluntary versus mandatory. Corps nonstructural projects can be either voluntary or mandatory in terms of property owner participation. This can be an issue with the nonstructural measure implementation that is not an issue of the structural measure implementation since, by definition, nonstructural measures directly impact the consequences (development) in floodplains. Voluntary is always the preferred method of implementation. However, often with voluntary participation by property owners within the normal timeframe of Corps project implementation, not all property owners desire to participate. If this is the case, mandatory implementation may be needed in order to achieve the overall objectives of the project. If mandatory, the local community may have to exercise condemnation authority. This is generally politically unacceptable unless proper State, local government, property owner, media, and political coordination has occurred to achieve "buy in" to that concept. Normally, voluntary or mandatory implementation becomes the greatest impact on the nonstructural measures of buyout and relocation where people and structures are removed or moved from the floodplain. With buyout and relocation, all property owners really need to participate in order to be able to implement the concept of "new uses of the evacuated floodplain" within the Corps project. Within this concept, the Corps project will incorporate not only reducing the flood risk in the floodplain by removal of property subject to flooding but will also convert the land to a "new use" such as recreation and/or ecosystem restoration that is compatible with the natural and beneficial aspects of EO 11988 and is long term sustainable with minimal input of resources by the local community who must do the OMRRR on the project in perpetuity. Without the ability to convert floodplains to such new uses because some property owners remain, the community must not only expend funds to do such things as mow the vacant lots but must also continue to provide services to the area such as utilities, streets, snow removal, etc, etc.

<u>1.8.10 Uniform relocation act (Public Law 91-646)</u>. This Public Law relates to the nonstructural measures of relocation and buyout only. With these measures, property owners and tenants are relocated from their pre project property where they live. The provisions of this PL apply to mandatory relocation of buyout nonstructural projects only and do not apply to a pure voluntary relocation and buyout project. This PL provides monetary benefits to people relocated from where they live by the project with the intent that the impacts of relocation on such people is as minimal as possible.

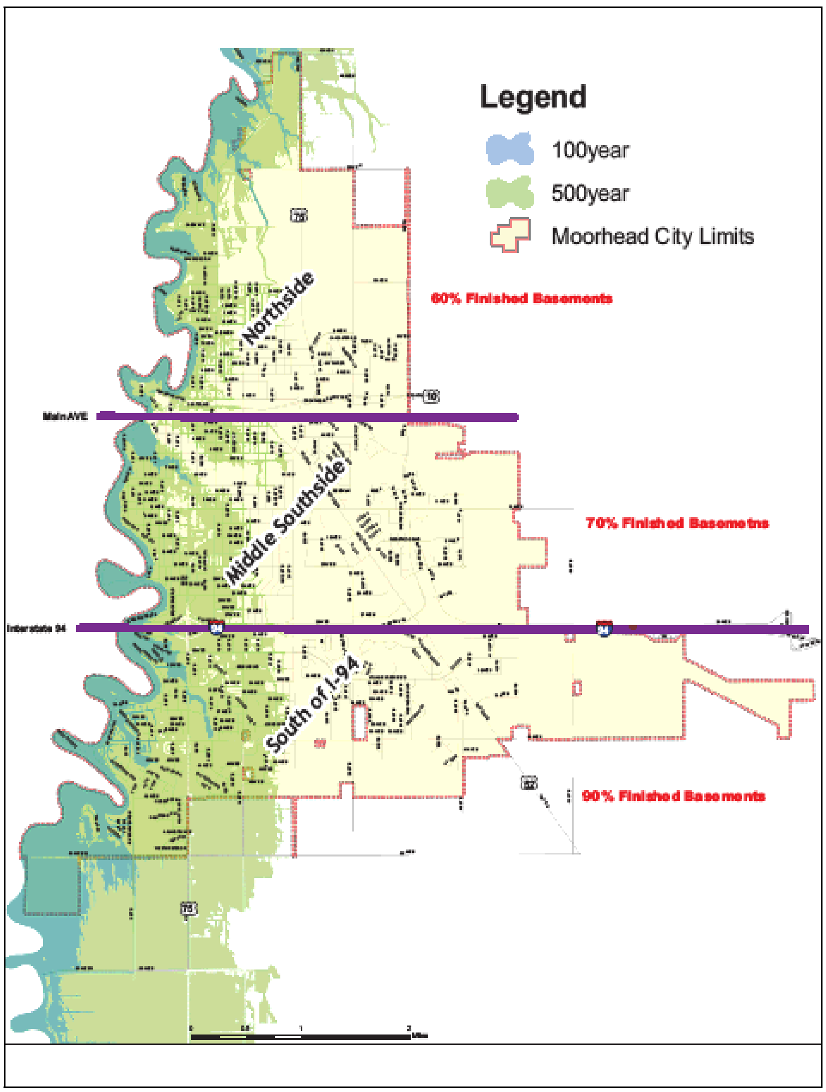
<u>1.8.11 Nonstructural project feasibility.</u> Within any nonstructural analysis to determine economic feasibility, some structures, if examined on an individual basis, may not be economically feasible even though the entire group of structures of which these individually infeasible structures are located, is feasible. Within any nonstructural economic feasibility analysis, the determination of economic feasibility will not be based on individual structure feasibility but will be based on groups of structures. This makes nonstructural economic feasibility on the same basis as economic feasibility for structural measures.

2.0 Nonstructural Techniques Used in Assessing Residential Structures

Nonstructural flood risk reduction techniques used for residential structures include elevating the entire structure, elevating the main floor, wet flood proofing, and permanent acquisition (buyout). Additional methods can be combined with the methods listed above such as filling in basements, constructing additions to compensate for lost square footage, and building additions to house utilities.

Basements are common in the Fargo-Moorhead area. Since figuring out which structures had finished or unfinished basements would require a structure by structure survey, which is outside the scope for this assessment, the cities provided us with the following information. In Fargo, structures that were constructed before 1970 had 50% finished basements, and 90% finished after 1970. In Moorhead, the city provided a map outlining the estimated percent of finished basements by location, which is shown in figure 2.

Figure 2
Estimated Percent of Finished Basements in Moorhead



2.1 Elevating Entire Structure

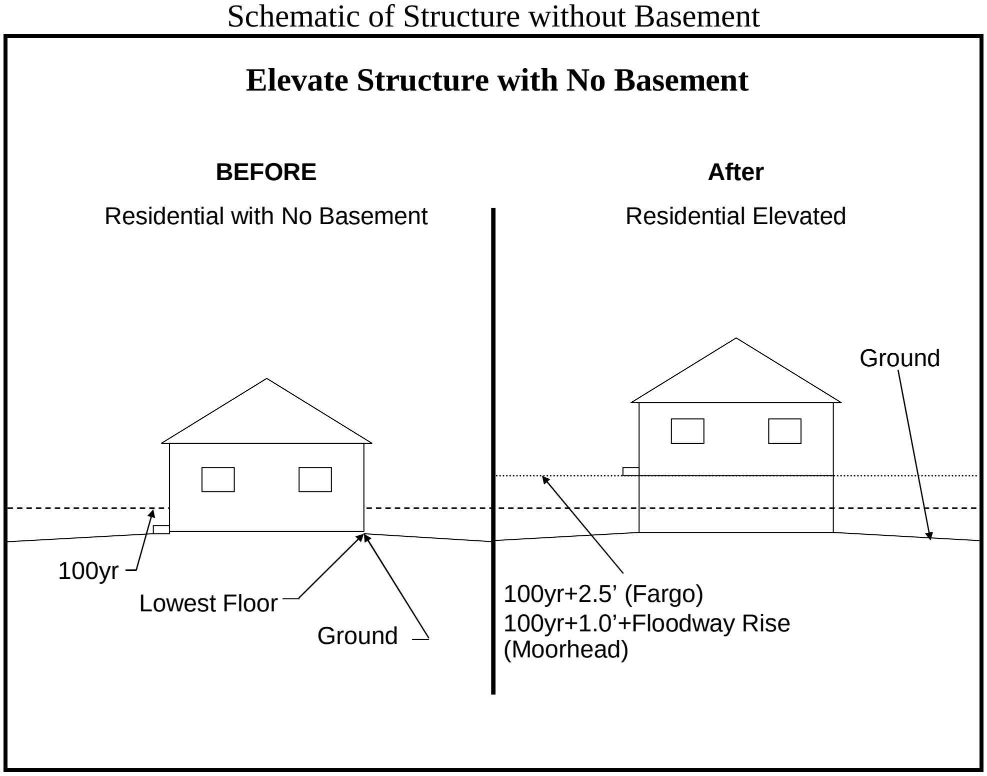
Elevating the entire structure requires raising the structure up from its original footings to an elevation above the design flood elevation. This technique was used on residential structures with and without basements and bi-level structures. To calculate the vertical distance of rise for each structure on the Fargo side, the stage of the 100-yr flood was used and then 2.5 feet was added per the guidelines listed in the Floodproof Construction Requirements for the City of Fargo, then the lowest level stage was subtracted. For structures on the Moorhead side, the stage of the design flood was used and then 1 foot plus the average floodway rise (0.8 ft.) was added. This design elevation was then subtracted from the structures lowest level stage. For the 200-yr and 500-yr flood events the water surface elevations were greater then 2.5 feet above the 100-yr event. These elevations were used directly with the lowest elevation stage to determine the vertical distance of the raise. The structures with raises less than 12 feet were analyzed with this technique. The cost to elevate the structure was figured by utilizing the equations base on structure square footage and listed in Table 2.

Table 2
Estimated Cost to Elevate Structures

Square Foot Range	**Cost to Elevate Equations**
0 - 1250	1000 x (3.100 x MF_Rise + 87.5)
1250 - 1750	1000 x (3.233 x MF_Rise + 91)
1750 - Greater	1000 x (3.533 x MF_Rise + 101)

Figure 3 is an example of a residential structure without a basement before and after this nonstructural flood reduction technique.

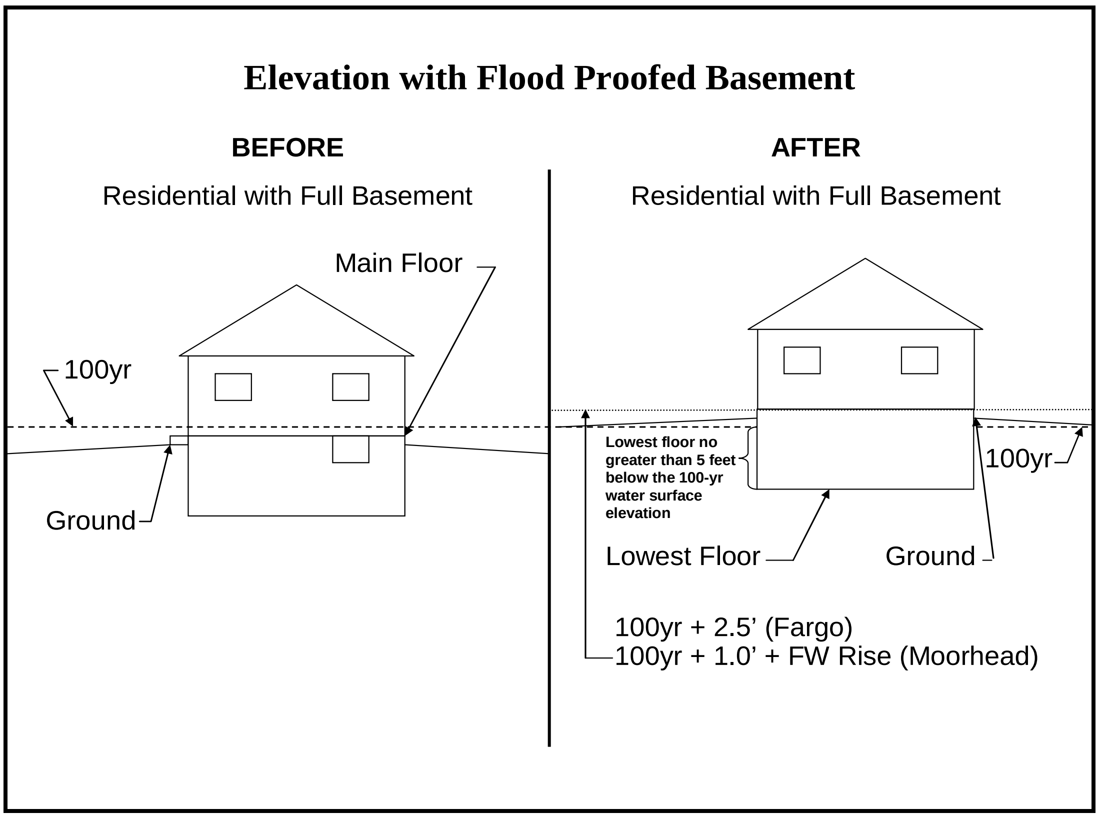
Figure 3
Schematic of Structure without Basement



2.2 Elevation with Dry Flood Proofed Basement

The City of Fargo and the City of Moorhead both have a basement exemption. A basement exemption allows a basement to be present in a residential structure in the floodplain when the structure follows strict building codes. Elevating with dry flood proofing was used for residential structures when elevating the basement level up would be greater then 12 feet. For these structures the main level was elevated above the design elevation and new basement would be constructed following the flood proofing guidelines. The same cost estimating equations were used based on the vertical distance of elevations in Table 2. An example is shown (Figure 4) of a residential structure with a basement before and after this nonstructural flood reduction technique.

Figure 4
Schematic of Elevated Structure with Flood Proofed Basement



2.3 Fill Basement with Main Floor Addition

Filling in the basement was an option for structures with flood depths below the main floor. The basement was filled with clean sand or fill. The area of the structure was provided by the St. Paul District. To compensate for the lost area, the owner of the structure was either paid for the loss of the basement or if feasible an addition was built above the design event. The size of the addition was based on 75% of the total area of a finished basement and 50% of the total area of an unfinished basement. Cost estimates for the fill and the loss of the basement is summarized in Table 3. Cost estimates for the addition is summarized in Table 4. Figure 5 is a simple example of filling a basement and adding an addition to the residence.

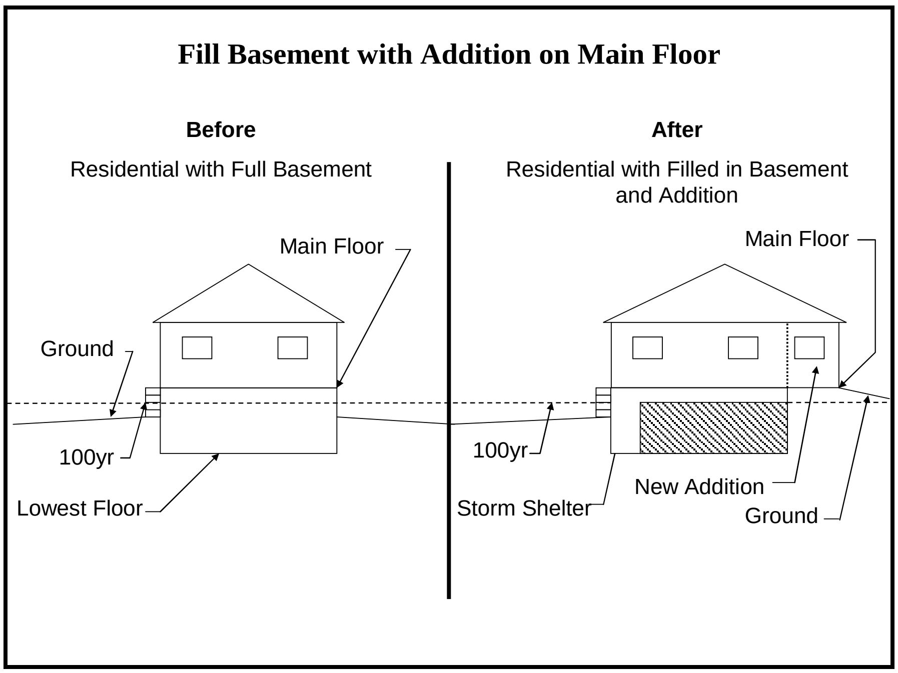
Table 3
Cost Estimating Parameters for Filling Basements for Residential Structures

Item:	**Cost/Units**	**Quantity**
Sand	$1.30/Cubic Foot	Area x 8 ft
Lost Square Footage (Unfinished)	13% of Structure Value	
Lost Square Footage (Finished)	37.5% of Structure Value	

Table 4
Cost for Addition to Residential Structures

Size	**100 Square Feet**	**500 Square Feet**	**750 Square Feet**	**1000 Square Feet**	**1500 Square Feet**
Cost	$21,000.00	$95,000.00	$134,100.00	$171,700.00	$247,300.00

Figure 5
Schematic of Structure with Basement Filled in and Addition on Main Floor



2.4 Permanent Acquisition (Buyout)

Buyout of residential structures requires buying the structure and the land and either demolishing the structure or relocating it to a place that is out of the floodplain. This nonstructural method was applied to structures that are located within the regulatory floodway, fell within the 450 ft buffer of the Red River of the North that was put in place by the City of Fargo, or had a depth of flooding on the structure greater than 12 feet. This method was also applied to structures that fell with in the “green space” corridors that were identified by city officials from Fargo and Moorhead. Costs for this estimate were figured by taking the structure value plus the land value, which were provide by St. Paul District, and multiplying that figure by a multiplier of 1.18. Figure 6 shows a neighborhood where a buyout program was implemented.

Figure 6
Residential Neighborhood after Buyout and Removal of Structure

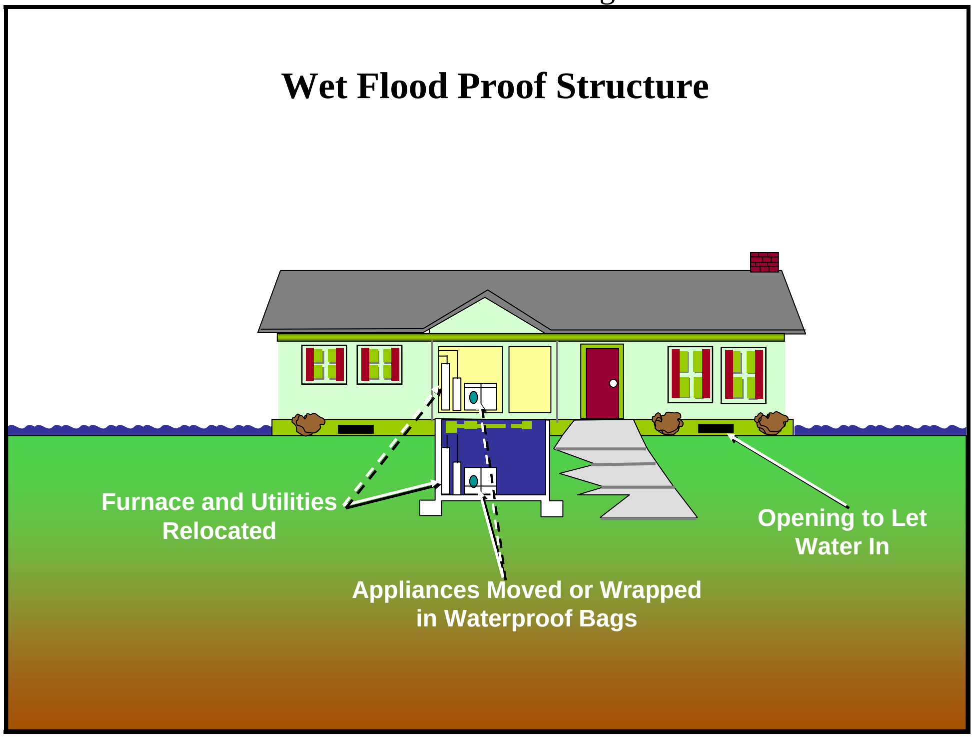
2.6 Wet Flood Proof

Wet flood proofing requires that water can enter the structure but not cause extensive damage to the structure. It basically could be hosed out and dried and be back to pre-flood event condition. Water must be permitted to flow freely in and out of the structure to equalize hydrostatic pressures on the structure to prevent failure of the walls and foundation. All utilities must be raised, or removed and installed in an addition that is located above the design event. This nonstructural method was applied to structures that had basements, but were unfinished, and the main floor elevation was above the design flood elevation. Costs for this estimate were figured by paying the homeowner for lost square footage, which amounted to 13% of the structure value. Cost for raising or relocating the utilities, and installing flood vents in the walls is summarized in Table 5. The square footage of the structures was provided to us by St. Paul District. Figure 7 illustrates wet flood proofing a residential structure.

Table 5
Cost estimating parameters for wet flood proofing residential structures

Item:	**Cost/unit**	**Quantity**
Removing Flood Damageable Materials	$3,900	1
Flood Vents	$472 each	6

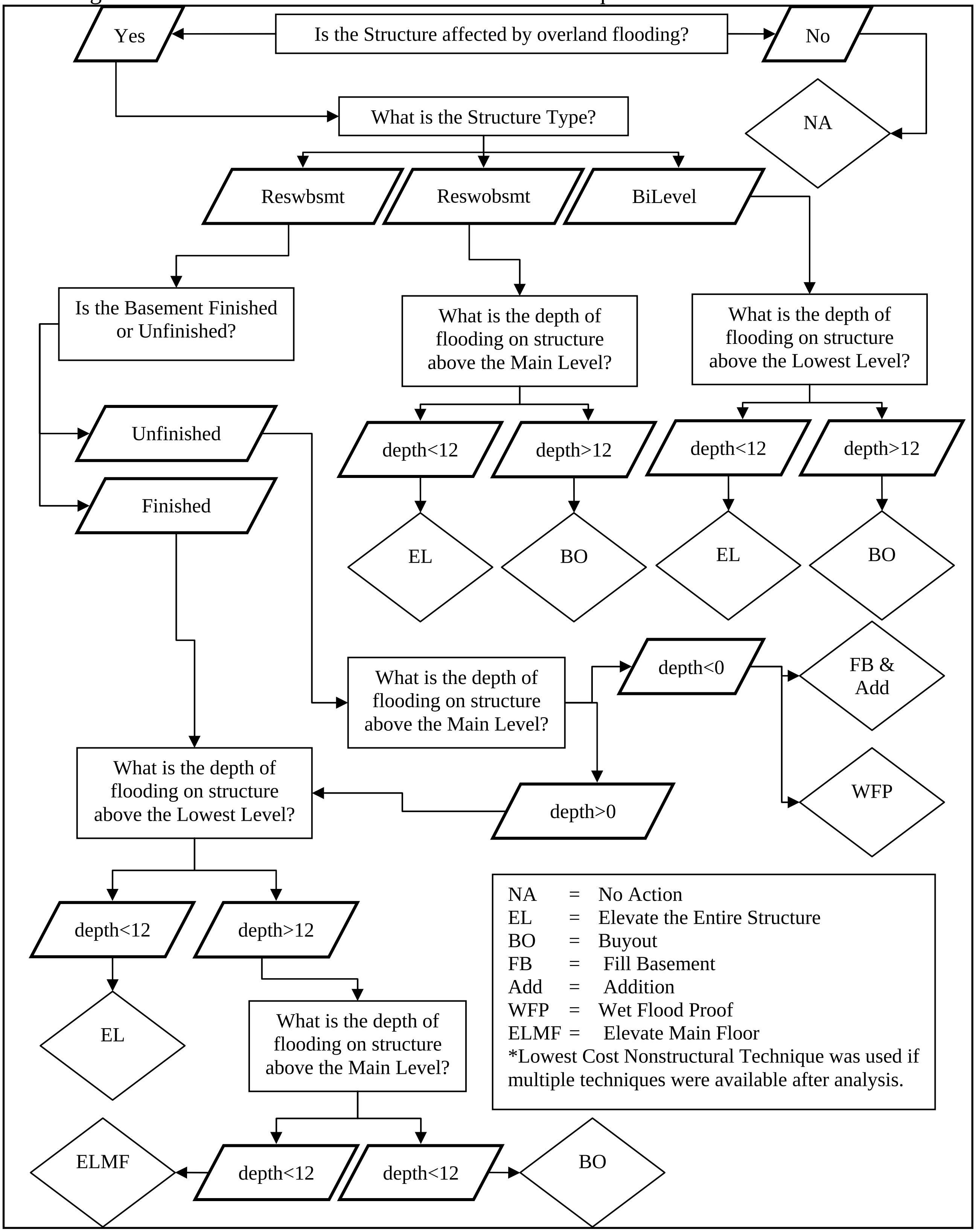
Figure 7
Wet Flood Proofing



2.7 Nonstructural Flood Risk Reduction Technique Selection Flow Chart

Figure 8 shows a general flow chart of developing the nonstructural flood risk reduction techniques. Also to select a flood risk reduction technique the lowest cost solution was used unless the criteria for selection overruled as is the case for the permanent acquisition structures.

Figure 8 - Nonstructural Flood Risk Reduction Technique Selection Flow Chart



3.0 Nonstructural Techniques Used in Assessing Commercial Structures.
Nonstructural flood risk reduction techniques used for commercial structures include dry flood proofing, elevating the entire structure, constructing floodwalls, permanent acquisition (buyout), relocation of structures and wet flood proofing. These techniques can be combined and the additional techniques are filling basements with a dry flood proofed main floor, filling basements with a constructed floodwall. This list of techniques is long because each commercial structure often has unique characteristics. This report section will describe how each of these techniques was used in the nonstructural analysis and how the cost estimates was completed.

Basements are common in the Fargo-Moorhead Area. Table 6 summarizes the structures with and without basements based on their Hydrologic Engineering Center- Flood Damage Reduction Analysis (HEC-FDA) occupancy code.

Table 6
Summary of commercial properties identified in the HEC-FDA analysis by occupancy name and occupancy description.

HEC-FDA: Occupancy Name	HEC-FDA: Occupancy Description	Assigned Basement	Assigned Basement Type
Apt1	Apt on slab (Apartment - one story)	No Basement	----------
Apt2	Apt w/ FF -4' (Apartment - one story)	Basement	Finished
102	Gas station w/ svcs (Service station)	No Basement	----------
103	Drug, grocery chain stores (Grocery)	No Basement	----------
104	Department stores - Sears, Penney's, etc.	No Basement	----------
105	Hardware, paint, sporting goods, auto parts stores	Basement	Finished
106	Barber and beauty shops	Basement	Unfinished
107	Laundromat, cleaners	Basement	Unfinished
108	Bakeries, quick shop (?)	No Basement	----------
109	Fast food - Dairy Queen, A&W, etc.	No Basement	----------
110	Rest., larger fast foods - McDonald's, etc.	No Basement	----------
111	Fashion, shoe, etc. stores (Clothing)	Basement	Finished
112	Liquor store, tavern	Basement	Unfinished
113	Bowling alley	No Basement	----------
114	Wrhse, storage bldg (Wrhse - non-refrig)	No Basement	----------
115	General office - doctor, realtor, bank, etc.	Basement	Unfinished
116	School, church (School, church combined)	Basement	Finished
130	Newspaper office	Basement	Finished
131	Small theater	No Basement	----------
132	Motel (Hotel/motel)	No Basement	----------
133	Funeral home	Basement	Finished
229	Wrhse/off comb, (Wrhse non-refrig)	No Basement	----------
27	Antique store	Basement	Finished
29	Auto dealer	No Basement	----------

HEC-FDA: Occupancy Name	HEC-FDA: Occupancy Description	Assigned Basement	Assigned Basement Type
401	Community hall - VFW, Legion, etc.	Basement	Finished
405	Mach. shop, small mnfctrg (Light mnftrg)	No Basement	----------
50	Dental office (Medical office)	Basement	Unfinished
52	Hospital (Hospital)	Basement	Finished
56	Florist	Basement	Unfinished
59	Furniture store (Furniture store)	Basement	Finished
72	Jewelry store	Basement	Unfinished
97	TV repair shop	Basement	Unfinished
98	Miscellaneous	Basement	Finished
Pub1	Public property - less damageable type	No Basement	----------
Pub2	Public property - more damageable type	Basment	Finished
Farmstead	Farmstead	No Basement	----------
Storage	Ag storage buildings	No Basement	----------
College1	College bldgs with FF at ground	No Basement	----------
College2	College bldgs with FF 4' below ground	Basement	Unfinished
BsmtUnfin	Dwntwn comml bsmts unfinished	Basement	Finished
BsmtFin	DwnTtwn comml bsmts finished	Basement	Unfinished

3.1 Dry Flood Proofing

Dry flood proofing for commercial structures involves applying a water resistant sealant around the structure to prevent flood water from entering. Doorways and windows are sealed with flood shields or by similar method. Cost estimates were developed for structures without basements and design flood depths of less than 3 feet. The costs used in the estimate are summarized in Table 7. The outside perimeter of a structure was determined by the building footprint shapefile provided by St. Paul District.

Table 7
Cost estimating parameters for dry flood proofing commercial structures.

Item:	Cost/unit	Quantity
Spray-on Cement (1/8 inch)	$5.00/feet squared	Perimeter x Flood Depth
Asphalt (2 Coats below grade)	$2.00/feet squared	Perimeter x Flood Depth
Periphery Drainage	$35.00/feet	Perimeter
Flood Shields (metal)	$110 Each	2 (used as estimate)

3.2 Elevate Entire Structure

Elevating the entire structure requires raising the structure up from its original footings and to an elevation above the design flood elevation. For commercial structures, elevating the entire structure was not considered as a primary technique of nonstructural flood risk reduction. This was due to the general large area when compared to residential construction and construction materials of most commercial buildings. Only a small number of commercial structures having a small structure footprint were elevated. Costs for these structures were estimated through the same cost equations used for elevating residential structures as described in Sections 2.1.

3.3 Floodwall

Structures with and without basements, and flood depths less then 12 feet were analyzed for this nonstructural flood risk reduction method. For buildings with basements, a floodwall extending to the footings of the building is required to prevent flood water from seeping under the floodwall and creating damages. For structures without basements, the floodwall extends to the lowest adjacent grade. Costs were determined on a linear foot basis and the length was determined by the outside perimeter of the structure. The cost per linear foot is summarized in Table 8 for floodwall heights 0 to 12 feet.

Table 8
Cost estimating parameters for floodwall for commercial structures.

Height (ft)	Cost/Linear Feet
0-6	$356
7	$498
8	$501
9	$615
11	$696
12	$803

3.4 Fill Basement

Structures with flood depths below the main floor elevation with basements were analyzed for this nonstructural flood risk reduction method. The basements were filled with sand or clean fill. The cost estimate information is summarized in Table 9. The basement area of a structure was determined by the building footprint shapefile provided by St. Paul District. The basements were assumed to have a depth of 8 feet. In addition to the cost of filling in the basement, the removal of building square footage requires compensation and the cost schedule is also summarized in Table 9.

Table 9
Cost estimating parameters for filling basements for commercial structures.

Item:	Cost/unit	Quantity
Sand	$1.30/cubit feet	Area x 8ft
Lost Square Footage (Unfinished)	13% of Structure Value	
Lost Square Footage (Finished)	37.5% of Structure Value	

3.5 Fill Basement and Dry Flood Proof

Structures with flood depths less than 3 feet above the main floor elevation with basements were analyzed for this nonstructural flood risk reduction method. The basements were filled with sand or clean fill. The exterior of the remaining existing building would be dry flood proofed. It is important that the basement level be entirely filled and sealed to prevent floodwater from infiltrating the filled area and subsequently infiltrating the main floor. The cost estimating information for this method is summarized in Tables 7 and Table 9.

3.6 Fill Basement and Construct Floodwall

Structures with flood depths less than 12 feet with basements were analyzed for this nonstructural flood risk reduction method. The basements were removed by filling them with sand or clean fill. The remaining existing structure would be protected by a flood wall. The floodwall would have openings for building entry and access for deliveries. These opening would be closed with a structural component during high water scenarios to provide continuous protection to the structure. The height of the floodwall was set by the design water elevation to lowest adjacent grade. The cost estimate information for this method is summarized in Tables 3 and Table 8.

3.7 Permanent Acquisition (Buyout)

The criterion for commercial structures to be identified as permanent acquisition was based on location and flood depth. For structures located in the floodway or located within a 450 feet buffer zone from the centerline of the Red River of the North were identified as permanent acquisition structures. Structures in the floodway decrease flood flow. It is advantages to remove these structures and return the floodway back to a natural condition. The 450 feet buffer zone was establish by the communities as a guide to prevent sloughing of the river bank into the channel. In addition to the above criterion, structures located in an oxbow were identified as permanent acquisition structures. Structures with flood depths greater than 12 feet were also identified as permanent acquisitions. The costs were estimated for these properties through collaboration with St. Paul District. The data from the acquisitions of properties in the communities of Grand Forks, North Dakota and East Grand Forks, Minnesota were reviewed and a general multiplier was established, as shown in table 10. The multiplier established was then applied to the tax assessor's structure and land value.

Table 10
Cost estimating parameters for permanent acquisition multipliers

Structure Type	Multiplier
Residential	1.18
Commercial	1.29

3.8 Wet Flood Proof

Structures with flood depths below the main floor elevation with basements were analyzed for this nonstructural flood risk reduction method. The basements of these structures were stripped of material damageable by flood waters. The only required action after the flood would be hose out the basement. Flood vents were installed to allow floodwaters to equalize between the exterior and interior of the basements. The cost to remove the damageable materials and the number of flood vents would greatly vary from structure to structure. With additional data not available, values were estimated based on average cost and square footage. The removal of building square footage requires compensation and the cost schedule is also summarized in Table 9. The additional costs estimating parameters for these properties are summarized in Table 11.

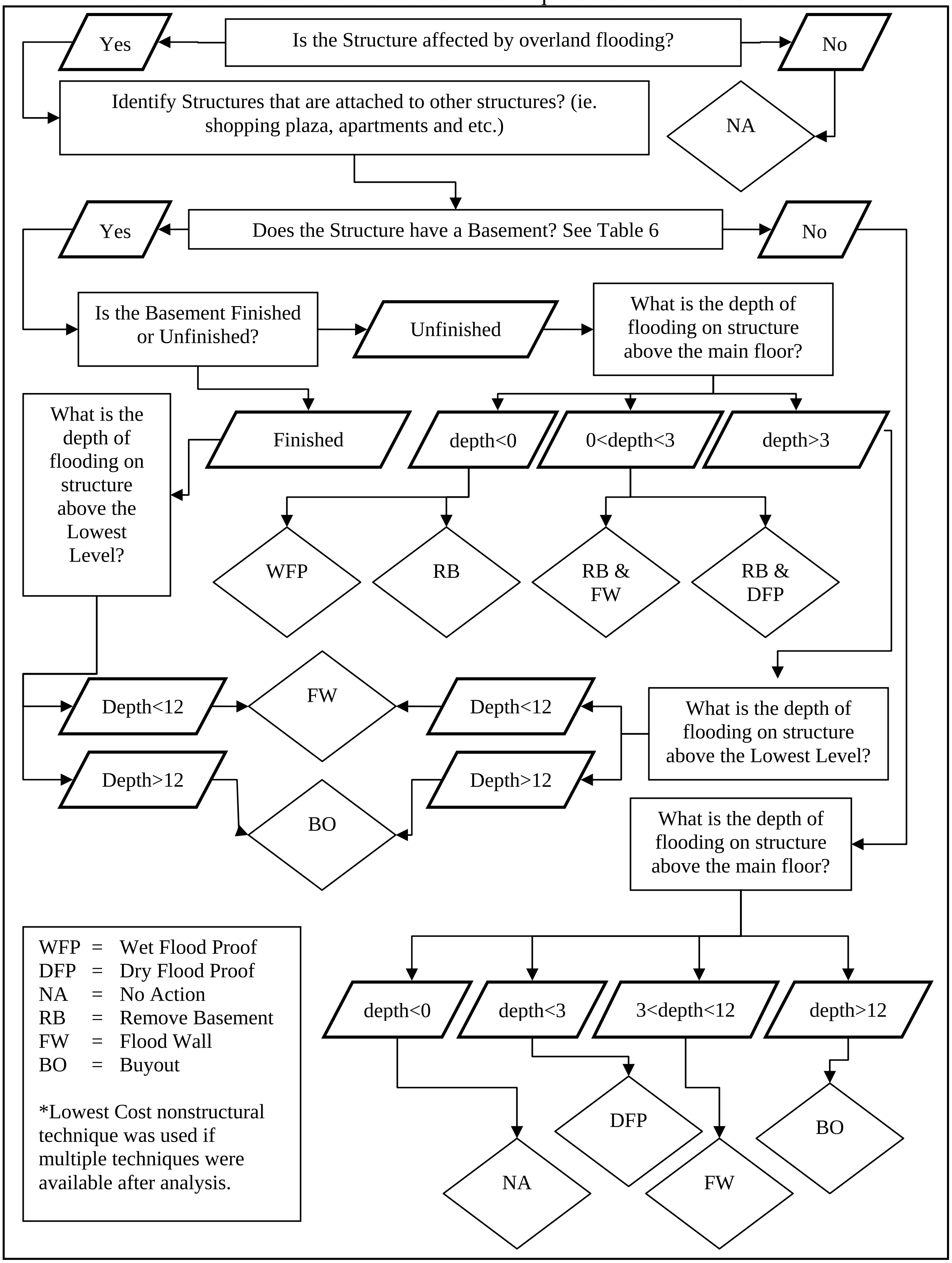
Table 11
Cost estimating parameters for wet flood proofing commercial structures

Item:	**Cost/unit**	**Quantity**
Removing Flood Damageable Materials	$3,900	1
Flood Vents	$472 each	6

3.9 Nonstructural Flood Risk Reduction Technique Selection Flow Chart

Figure 9 shows a general flow chart of developing the nonstructural flood risk reduction techniques. Also to select a flood risk reduction technique the lowest cost solution was used unless the criteria for selection overruled as is the case for the permanent acquisition structures.

Figure 9
Nonstructural Flood Risk Reduction Technique Selection Flow Chart



4.0 Nonstructural Techniques Used in Assessing Critical Facilities

As with the residential and commercial structures, the critical facilities were evaluated in their respective economic regions. These were Cass County North, Cass County South, Fargo North, Fargo South, and Moorhead.

Locations and information for Critical facilities that were evaluated in this study were provided by Cass County, North Dakota, and City governments of Fargo, North Dakota and Moorhead, Minnesota. Unlike the residential and commercial facilities, the critical facilities were only evaluated and flood proofed to the 0.2% chance annual flood (500-yr). Under Executive Order 11988, Floodplain Management, critical facilities are required to be protected to the 0.2 percent annual chance flood so they can be operational during an emergency.

4.1 Relocate

Relocation of critical facilities requires physically moving the structure from an area of high flood hazard to an area of lower flood hazard and then purchasing the property on which the structure was located. This nonstructural method was only applied to structures that were either in the regulatory floodway or had a depth of flooding on the structure of 12 feet or greater. Costs for this estimate were figured by taking the structure value plus the land value, multiplied by a cost multiplier of 1.29.0

4.2 Dry Flood Proof

Dry flood proofing critical facilities requires applying a sealant around the structure to prevent flood waters from entering the structure. Entrances and windows will be sealed by using bolt on or slide in place flood shields. This nonstructural method was only applied to structures without basements and for flood depths of less than 3 feet. Costs for this estimate are summarized in Table 12. The perimeter was determined from the building footprints provided by St. Paul District.

Table 12
Cost Estimating Parameters for Dry Flood Proofing Critical Facilities

Item:	**Cost/Units**	**Quantity**
Spray on Cement (1/8 inch)	$5.00/Square Foot	Perimeter x Flood Depth
Asphalt (2 Coats below grade)	$2.00/Square Foot	Perimeter x Flood Depth
Periphery Drainage	$35.00/Each	Perimeter
Flood Shields (metal)	$110.00 Each	2 (Used as Estimate)

4.3 Floodwall

Structures with and without basements, and flood depths below 12 feet were analyzed for this nonstructural flood risk reduction method. For structures with basements the floodwall was extended down to the footings to prevent flood waters from seeping under the floodwall and causing damages to occur. For structures without basements the floodwall extends to the lowest adjacent grade. Floodwall cost was determined on a linear foot basis as shown in Table 13. This was determined by the building footprints which were provided by the St. Paul District.

Table 13
Cost Estimate for Floodwalls. For use in Critical Facilities

Height	Cost/Linear Foot
0-6	$356
7	$498
8	$501
9	$615
11	$696
12	$803

5.0 100-Year Stand-Alone Nonstructural Flood Risk Reduction Plan

For the Fargo-Moorhead Metro Area the 100-yr floodplain would inundate approximately 11,300 structures. These structures include residential, commercial, and public structures and are summarized by economic subunit in Table 14. The water surface elevations for the 100-yr project were determined from the existing conditions first generation hydraulic modeling completed by St. Paul District prior to July 2009. The structures were identified as being in the 100-yr floodplain if the difference in the 100-yr water surface elevation and the ground elevation was greater than zero. It is important to note here that the structures were not selected based on 100-yr floodplain delineations and the structure location.

Table 14
Residential, Commercial and Critical Facilities Summary by Economic Subunits for the 100-yr Nonstructural Flood Risk Reduction Plan

Economic Subunit	Total Residential Structures	Total Commercial Structures	Total Critical Facilities
100yr Plan			
Cass County North	176	5	1
Cass County South	266	7	1
Fargo North	2,975	1,658	23
Fargo South	3,848	829	9
Moorhead	1,437	102	57
Total	8,702	2,601	91

5.1 Plan Development

For the nonstructural flood risk reduction analysis of the Fargo-Moorhead Metro Area, a number of valuable datasets were obtained. The City of Fargo, City of Moorhead, Cass County, North Dakota and U.S. Army Corps of Engineers, St. Paul District provided the data for this study.

Detailed structure and economic data was provided by St. Paul District. The economic data was in the form of HEC-FDA output files and the files were the initial base data used to begin the analysis. For the economic analysis, the St. Paul District completed the assembly of ground elevations and foundation height for each structure in the Fargo-Moorhead Area. The ground elevations were extracted from Light Detection and Ranging (LiDAR) survey data and the foundation heights were determined by visually estimating the vertical distance from the ground and the foundation. The files provided occupancy type, property values, structure types, water surface elevations, ground surface elevations, and first floor elevations.

Structure GIS data was provided by St. Paul District and supplemented through the city and county GIS departments. The data was valuable to determine the spatial locations of the structures in the economic analysis. The files provided structure location, plan view area and footprint. The economic data and structure GIS data were joined together through ArcMap and used as the base data.

Hydraulic data was provided by the St. Paul District. The hydraulic model included cross sections for the Red River of the North. The elevations from the hydraulic model were used to determine the water surface elevation at each structure. The water surface elevations had already been assigned to the structures in the structure data provided from the economic analysis. The elevations were checked to the hydraulic model and found to be in good agreement.

5.2 Summary of 100-Year Stand-Alone Nonstructural Plan

The 100-yr nonstructural flood risk reduction plan was completed for five economic subunits. The subunits include Moorhead, Cass County North, Cass County South, Fargo North and Fargo South. In these five economic subunits, the residential structures were divided into three occupancy types; residential structures with basements, residential structures without basements, and bi-level homes. The occupancy types for commercial structures were not divided for separate analysis. Apartments, college and storage structures were included in the commercial analysis. Additionally, no separation was made for industrial structures.

Nonstructural flood risk reduction techniques were assigned to the structure based on the criteria discussed in Report Sections 2.2 and 2.3. These structures and techniques are summarized in Tables 15 to Table 19.

Table15

Cass County North 100-Year Nonstructural Flood Risk Reduction Summary Table

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	81	26,264,558	324,254
Elevate the Main Floor	13	1,395,537	107,349
Elevate the Entire Structure	46	5,720,867	124,367
Bi-level Homes			
Buyout	23	5,236,486	227,673
Elevate the Entire Structure	12	1,415,785	117,982
Residential Structures Without Basements			
Buyout	0	0	0
Elevate the Entire Structure	0	0	0
Total Residential			
Buyout	104	31,501,044	302,895
Elevate the Main Floor	13	1,395,537	107,349
Elevate the Entire Structure	58	7,136,652	123,046
Total Residential Cost of Nonstructural Flood Risk Reduction		**$40,033,233**	
Commercial Structures			
Dry Flood Proof	3	61,545	20,515
Remove Basement Dry FP	1	81,198	81,198
Flood Wall	1	401,500	401,500
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$544,243**	
Total 100yr Plan Cost in Cass County North		**$40,577,476**	

Table 16
Cass County South 100-Year Nonstructural Flood Risk Reduction Summary Table

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	83	23,700,182	285,544
Elevate the Main Floor	9	1,015,308	112,812
Elevate the Entire Structure	70	9,690,437	138,435
Bi-level Homes			
Buyout	41	10,102,924	246,413
Elevate the Entire Structure	62	7,227,625	116,575
Residential Structures Without Basements			
Buyout	0	0	0
Elevate the Entire Structure	0	0	0
Total Residential			
Buyout	124	33,803,106	272,606
Elevate the Main Floor	9	1015307.76	112,812
Elevate the Entire Structure	132	16,918,062	128,167
Total Residential Cost of Nonstructural Flood Risk Reduction		**$51,736,475**	
Commercial Structures			
Floodwall	8	1,304,775	163,097
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$1,304,775**	
Total 100-yr Plan Cost for Cass County South		**$53,041,250**	

Table 17
Fargo North Economic Area 100-Year Nonstructural Flood Risk Reduction
Plan Summary Table

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	132	28,398,352	215,139
Elevate the Main Floor	119	12,914,264	108,523
Elevate the Entire Structure	2,260	274,299,760	121,372
Fill Basement w/ Addition	10	415,000	41,500
Wet Flood Proof	6	232,517	38,753
Bi-level Homes			
Buyout	51	7,481,790	146,702
Elevate the Entire Structure	346	40,169,130	116,096
Residential Structures Without Basements			
Buyout	0	0	0
Elevate the Entire Structure	14	933,512	66,679
Total Residential			
Buyout	183	35,880,142	196,066
Elevate the Main Floor	119	12,914,264	108,523
Elevate the Entire Structure	2,620	315,402,402	120,383
Fill Basement w/ Addition	10	415,000	41,500
Wet Flood Proof	6	232,517	38,753
Total Residential Cost of Nonstructural Flood Risk Reduction		**$364,844,325**	
Commercial Structures			
Buyout	31	37,209,147	1,200,295
Dry Flood Proof	262	5,859,854	22,366
Fill Basement	38	1,304,926	34,340
Flood Wall	193	36,923,371	191,313
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$81,297,298**	
Total 100-yr Plan Cost in Fargo North		**$446,141,623**	

Table 18
Fargo North Economic Area 100-Year Nonstructural Flood Risk Reduction
Plan Summary Table

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	272	114,289,018	420,180
Elevate the Main Floor	74	8,623,047	116,528
Elevate the Entire Structure	1,518	201,798,377	132,937
Bi-level Homes			
Buyout	47	12,744,236	271,154
Elevate the Entire Structure	1,692	189,385,349	111,930
Residential Structures Without Basements			
Buyout	0	0	0
Elevate the Entire Structure	245	19,318,403	78,851
Total Residential			
Buyout	319	127,033,254	398,223
Elevate the Main Floor	74	8,623,047	116,528
Elevate the Entire Structure	3,455	410,502,129	118,814
Total Residential Cost of Nonstructural Flood Risk Reduction		**$546,158,430**	
Commercial Structures			
Buyout	106	87,636,150	826,756
Dry Flood Proof	483	3,195,972	6,617
Fill Basement	21	1,476,182	70,294
Fill Basement w/ Floodwall	49	9,140,599	186,543
Floodwall	84	19,076,786	227,105
Wet Flood Proof	8	1,008,987	126,123
No Action	78	0	0
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$121,534,677**	
Total 100-yr Plan Cost in Fargo South		**$667,693,106**	

Table 19
Fargo South Economic Area 100-Year Nonstructural Flood Risk
Reduction Plan Summary Table

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	511	116,007,806	227,021
Elevate the Main Floor	322	37,371,274	116,060
Elevate the Entire Structure	502	68,088,788	135,635
Fill Basement w/ Addition	84	4,567,400	54,374
Bi-level Homes			
Buyout	6	865,530	144,255
Elevate the Entire Structure	12	1,603,026	133,585
Residential Structures Without Basements			
Buyout	1	57,060	57,060
Elevate the Structure	36	2,663,353	73,982
Total Residential			
Buyout	518	116,930,396	225,734
Elevate the Main Floor	322	37,371,274	116,060
Elevate the Entire Structure	550	72,355,167	131,555
Fill Basement w/ Addition	84	4,567,400	54,374
Total Residential Cost of Nonstructural Flood Risk Reduction		**$231,224,237**	
Commercial Structures			
Buy Out	16	5,181,027	323,814
Dry	20	497,603	24,880
Elevate Structure	14	1,589,968	113,569
Floodwall	44	8,498,140	193,140
Relocate	7	1,775,814	253,688
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$17,542,552**	
Total 100-yr Plan Cost in Fargo South		**$248,766,789**	

5.3 Project Benefits

Project benefits were calculated by St. Paul District using HEC-FDA computer model. A modified with-project condition HEC-FDA input file was created for each economic subunit and the data was run in HEC-FDA to determine damages of the project condition. The difference between the pre-project and with-project damages was then used as the project benefits. Table 20 displays these benefits and benefit to cost ratios.

Table 20
Fargo-Moorhead Metro Nonstructural Flood Risk Reduction 100-Year Plan Summary

Unit	100- Year Plan Total Cost	100-Year Plan Estimated Annual Cost	100-Year Plan Estimated Annual Benefits	100-Year Plan Benefits to Cost	100-Year Plan Net Benefits
Cass County North	$43,458,596	$2,243,976	$584,216	0.26	-$1,659,760
Cass County South	$56,807,340	$2,933,235	$934,175	0.32	-$1,999,060
Fargo North	$477,819,023	$24,672,086	$13,526,428	0.55	-$11,145,658
Fargo South	$715,101,326	$36,924,108	$10,746,925	0.29	-$26,177,183
Moorhead	$266,429,979	$13,757,056	$2,403,667	0.17	-$11,353,389
Total 100-Year Plan	$1,559,616,264	$80,530,461	$28,195,411	0.35	-$52,335,050

6.0 200-Year Stand-Alone Nonstructural Flood Risk Reduction Plan

For the Fargo-Moorhead Metro Area the 200-yr floodplain would inundate approximately 29,254 structures. These structures include residential, commercial, and public structures and are summarized by economic subunit in Table 21. The water surface elevations for the 200-yr project were determined from the existing conditions first generation hydraulic modeling completed by St. Paul District prior to July 2009. The structures were identified as being in the 200-yr floodplain if the difference in the 200-yr water surface elevation and the ground elevation was greater than zero. It is important to note here that the structures were not selected based on 200-yr floodplain delineations and the structure location.

Table 21
Residential, Commercial and Critical Facilities Summary by Economic Subunits for the 200-Year Nonstructural Flood Risk Reduction Plan

Economic Subunit	Total Residential Structures	Total Commercial Structures	Total Critical Facilities
200yr Plan			
Cass County North	225	10	1
Cass County South	334	15	1
Fargo North	10,106	2,567	23
Fargo South	9,589	1,446	9
Moorhead	4,735	227	57
Total	24,989	4,265	91

6.1 Plan Development

For the nonstructural flood risk reduction analysis of the Fargo-Moorhead Metro Area, a number of valuable datasets were obtained. The City of Fargo, City of Moorhead, Cass County, North Dakota and U.S. Army Corps of Engineers, St. Paul District provided the data for this study.

Detailed structure and economic data was provided by St. Paul District. The economic data was in the form of HEC-FDA output files and the files were the initial base data used to begin the analysis. For the economic analysis, the St. Paul District completed the assembly of ground elevations and foundation height for each structure in the Fargo-Moorhead Area. The ground elevations were extracted from LiDAR survey data and the foundation heights were determined by visually estimating the vertical distance from the ground and the foundation. The files provided occupancy type, property values, structure types, water surface elevations, ground surface elevations, and first floor elevations.

Structure GIS data was provided by St. Paul District and supplemented through the city and county GIS departments. The data was valuable to determine the spatial locations of the structures in the economic analysis. The files provided structure location, plan view area and footprint. The economic data and structure GIS data were joined together through ArcMap and used as the base data.

Hydraulic data was provided by the St. Paul District. The hydraulic model included cross sections for the Red River of the North. The elevations from the hydraulic model were used to determine the water surface elevation at each structure. The water surface elevations had already been assigned to the structures in the structure data provided from the economic analysis. The elevations were checked to the hydraulic model and found to be in good agreement.

6.2 Summary of Plan

The 200-year nonstructural flood risk reduction plan was completed for five economic subunits. The subunits include Moorhead, Cass County North, Cass County South, Fargo North and Fargo South. In these five economic subunits, the residential structures were divided into three occupancy types; residential structures with basements, residential structures without basements, and bi-level homes. The occupancy types for commercial structures were not divided for separate analysis. Apartments, college and storage structures were included in the commercial analysis. Additionally, no separation was made for industrial structures.

Nonstructural flood risk reduction techniques were assigned to the structure based on the criteria discussed in Report Sections 2.2 and 2.3. These structures and techniques are summarized in Tables 22 to Table 26.

Table 22
Cass County North 200-yr Nonstructural Flood Risk Reduction Summary Table.

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	96	30,494,386	317,650
Elevate the Main Floor	13	1,248,740	96,057
Elevate the Entire Structure	69	6,954,800	100,794
Bilevel Homes			
Buyout	25	5,394,016	215,761
Elevate the Entire Structure	21	2,388,999	113,762
Residential Structures Without Basements			
Buyout	0	0	0
Elevate the Entire Structure	1	69,477	69,477
Total Residential			
Buyout	121	35,888,402	296,598
Elevate the Main Floor	13	1,248,740	96,057
Elevate the Entire Structure	91	9,413,276	103,443
Total Residential Cost of Nonstructural Flood Risk Reduction		**$46,550,418**	
Comercial Structures			
Dry Flood Proof	2	46,048	23,024
Remove Basement Dry FP	4	1,058,744	264,686
Flood Wall	3	965,450	321,817
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$2,070,242**	
Total 200-yr Plan Cost in Cass County North		**$48,620,660**	

Table 23
Cass County South 200-Year Nonstructural Flood Risk Reduction Summary Table.

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	70	22,455,046	320,786
Elevate the Main Floor	9	1,015,437	112,826
Elevate the Entire Structure	112	13,648,045	121,858
Wet Flood Proof	3	346,098	115,366
Bilevel Homes			
Buyout	33	7,452,762	225,841
Elevate the Entire Structure	106	12,008,741	113,290
Residential Structures Without Basements			
Buyout	1	298,540	298,540
Elevate the Entire Structure	0	0	0
Total Residential			
Buyout	104	30,206,348	290,446
Elevate the Main Floor	9	1,015,437	112,826
Elevate the Entire Structure	218	25,656,786	117,692
Wet Flood Proof	3	346,098	115,366
Total Residential Cost of Nonstructural Flood Risk Reduction		**$57,224,669**	
Commercial Structures			
Buy Out	1	1,032,000	1,032,000
Flood Wall	14	3,472,294	248,021
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$4,504,294**	
Total 200-yr Plan Cost in Cass County South		**$61,728,963**	

Table 24
Fargo North 200-Year Nonstructural Flood Risk Reduction Summary Table.

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	156	32,036,056	205,359
Elevate the Main Floor	120	12,980,847	108,174
Elevate the Entire Structure	6,908	814,883,467	117,962
Fill Basement w/ Addition	260	29,744,000	114,400
Wet Flood Proof	1,623	72,296,690	44,545
Bi-level Homes			
Buyout	17	3,206,060	188,592
Elevate the Entire Structure	1,000	108,520,591	108,521
Residential Structures Without Basements			
Buyout	0		
Elevate the Entire Structure	17	1,184,212	69,660
Total Residential			
Buyout	173	35,242,116	203,712
Elevate the Main Floor	120	12,980,847	108,174
Elevate the Entire Structure	7,925	924,588,269	116,667
Fill Basement w/ Addition	260	29,744,000	114,400
Wet Flood Proof	1,623	72,296,690	44,545
Total Residential Cost of Nonstructural Flood Risk Reduction		**$1,074,851,923**	
Commercial Structures			
Buyout	99	129,355,911	1,306,625
Dry Flood Proof	859	10,157,988	11,825
Fill Basement w/ Dry FP Main Floor	275	28,053,801	102,014
Fill Basement w/ Floodwall	599	74,182,435	123,844
Floodwall	589	93,562,675	158,850
Wet Flood Proof	42	3,221,204	76,695
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$338,534,014**	
Total 200-yr Plan Cost in Fargo North		**$1,413,385,936**	

Table 25

Fargo South 200-Year Nonstructural Flood Risk Reduction Summary Table.

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	200	78,545,638	392,728
Elevate the Main Floor	74	8,623,047	116,528
Elevate the Entire Structure	3,582	448,608,136	125,240
Wet Flood Proof	66	3,659,228	55,443
Fill Basement w/ Addition	31	3,546,400	114,400
Bi-level Homes			
Buyout	47	12,744,236	271,154
Elevate the Entire Structure	3,615	394,053,341	109,005
Residential Structures Without Basements			
Buyout	0	0	0
Elevate the Entire Structure	526	37,962,109	72,171
Total Residential			
Buyout	247	91,289,874	369,595
Elevate the Main Floor	74	8,623,047	116,528
Elevate the Entire Structure	7,723	880,623,585	114,026
Wet Flood Proof	66	3,659,228	55,443
Fill Basement w/ Addition	31	3,546,400	114,400
Total Residential Cost of Nonstructural Flood Risk Reduction		**$987,742,134**	
Commercial Structures			
Buyout	53	13,951,995	263,245
Dry Flood Proof	671	6,238,265	9,297
Fill Basement w/ Dry FP	74	12,770,319	172,572
Fill Basement w/ Floodwall	162	40,482,009	249,889
Floodwall	461	50,230,887	108,961
Wet Flood Proof	9	919,998	102,222
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$124,593,472**	
Total 200-yr Plan Cost in Fargo South		**$1,112,335,606**	

Table 26
Moorhead 200-Year Nonstructural Flood Risk Reduction Summary Table.

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	213	38,595,204	181,198
Elevate the Main Floor	508	60,559,989	119,213
Elevate the Entire Structure	3,143	403,554,637	128,398
Fill Basement w/ Addition	654	50,456,600	77,151
Bi-level Homes			
Buyout	9	1,924,344	213,816
Elevate the Entire Structure	46	5,949,579	129,339
Residential Structures Without Basements			
Buyout	1	185,850	185,850
Elevate the Entire Structure	92	7,582,665	82,420
Total Residential			
Buyout	223	40,705,398	182,535
Elevate the Main Floor	508	60,559,989	119,213
Elevate the Entire Structure	3,281	417,086,881	127,122
Fill Basement w/ Addition	654	50,456,600	77,151
Total Residential Cost of Nonstructural Flood Risk Reduction		**$568,808,868**	
Commercial Structures			
Buy Out	31	24,273,677	783,022
Dry	20	385,925	19,296
Floodwall	220	46,897,031	213,168
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$71,556,633**	
Total 200-yr Plan Cost in Moorhead		**$640,365,501**	

6.3 Project Benefits

Project benefits were calculated by St. Paul District using HEC-FDA computer model. A modified with-project condition HEC-FDA input file was created for each economic subunit and the data was run in HEC-FDA to determine damages of the project condition. The difference between the pre-project and with-project damages was then used as the project benefits. Table 27 displays these benefits and benefit to cost ratios.

Table 27
Fargo-Moorhead Metro Nonstructural Flood Risk Reduction 200-Year Plan Summary

Subunit	200- Year Plan Total Cost	200-Year Plan Estimated Annual Cost	200-Year Plan Estimated Annual Benefits	200-Year Plan Benefits to Cost	200-Year Plan Net Benefits
Cass County North	$48,620,660	$2,688,722	$621,768	0.23	-$2,066,954
Cass County South	$61,728,963	$3,413,674	$1,019,232	0.30	-$2,394,442
Fargo North	$1,413,385,936	$78,161,680	$43,340,376	0.55	-$34,821,304
Fargo South	$1,112,335,606	$61,513,290	$17,788,660	0.29	-$43,724,630
Moorhead	$640,365,500	$35,412,863	$3,663,416	0.10	-$31,749,447
Total 200-Year Plan	$3,276,436,665	$181,190,229	$66,433,451	0.37	-$114,756,778

7.0 500-Year Stand-Alone Nonstructural Flood Risk Reduction Plan

For the Fargo-Moorhead Metro Area the 500-yr floodplain would inundate approximately 33,183 structures. These structures include residential, commercial, and public structures and are summarized by economic subunit in Table 28. The water surface elevations for the 500-yr project were determined from the existing conditions first generation hydraulic modeling completed by St. Paul District prior to July 2009. The structures were identified as being in the 500-yr floodplain if the difference in the 500-yr water surface elevation and the ground elevation was greater than zero. It is important to note here that the structures were not selected based on 500-yr floodplain delineations and the structure location.

Table 28
Residential, Commercial and Critical Facilities Summary by Economic Subunits for the 500-Year Nonstructural Flood Risk Reduction Plan

Economic Subunit	Total Residential Structures	Total Commercial Structures	Total Critical Facilities
500yr Plan			
Cass County North	293	16	1
Cass County South	433	18	1
Fargo North	11,687	2,856	23
Fargo South	8,379	1,533	9
Moorhead	7,471	497	57
Total	28,263	4,920	91

7.1 Plan Development

For the nonstructural flood risk reduction analysis of the Fargo-Moorhead Metro Area, a number of valuable datasets were obtained. The City of Fargo, City of Moorhead, Cass County, North Dakota and U.S. Army Corps of Engineers, St. Paul District provided the data for this study.

Detailed structure and economic data was provided by St. Paul District. The economic data was in the form of HEC-FDA output files and the files were the initial base data used to begin the analysis. For the economic analysis, the St. Paul District completed the assembly of ground elevations and foundation height for each structure in the Fargo-Moorhead Area. The ground elevations were extracted from LiDAR survey data and the foundation heights were determined by visually estimating the vertical distance from the ground and the foundation. The files provided occupancy type, property values, structure types, water surface elevations, ground surface elevations, and first floor elevations.

Structure GIS data was provided by St. Paul District and supplemented through the city and county GIS departments. The data was valuable to determine the spatial locations of the structures in the economic analysis. The files provided structure location, plan view area and footprint. The economic data and structure GIS data were joined together through ArcMap and used as the base data.

Hydraulic data was provided by the St. Paul District. The hydraulic model included cross sections for the Red River of the North. The elevations from the hydraulic model were used to determine the water surface elevation at each structure. The water surface elevations had already been assigned to the structures in the structure data provided from the economic analysis. The elevations were checked to the hydraulic model and found to be in good agreement.

7.2 Summary of Plan

The 500-year nonstructural flood risk reduction plan was completed for five economic subunits. The subunits include Moorhead, Cass County North, Cass County South, Fargo North and Fargo South. In these five economic subunits, the residential structures were divided into three occupancy types; residential structures with basements, residential structures without basements, and bi-level homes. The occupancy types for commercial structures were not divided for separate analysis. Apartments, college and storage structures were included in the commercial analysis. Additionally, no separation was made for industrial structures.

Nonstructural flood risk reduction techniques were assigned to the structure based on the criteria discussed in Report Sections 2.2 and 2.3. These structures and techniques are summarized in Tables 29 to Table 33.

Table 29
Cass County North 500-Year Nonstructural Flood Risk Reduction Summary Table

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	127	39,902,998	314,197
Elevate the Main Floor	15	1,611,258	107,417
Elevate the Entire Structure	96	11,585,405	120,681
Bi-level Homes			
Buyout	28	6,191,814	221,136
Elevate the Entire Structure	26	2,959,546	113,829
Residential Structures Without Basements			
Buyout	0	0	0
Elevate the Entire Structure	1	69,983	69,983
Total Residential			
Buyout	155	46,094,812	297,386
Elevate the Main Floor	15	1,611,258	107,417
Elevate the Entire Structure	123	14,614,934	118,821
Total Residential Cost of Nonstructural Flood Risk Reduction		**$62,321,004**	
Commercial Structures			
Total Commercial			
Dry	4	100,152	25,038
Fill Basement/Dry Flood Proof	6	3,290,827	548,471
Fill Basement/Floodwall	1	108,035	108,035
Floodwall	3	994,772	331,591
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$4,493,786**	
Total 500-yr Plan Cost in Cass County North		**$66,814,790**	

Table 30
Cass County South 500-Year Nonstructural Flood Risk Reduction Summary Table

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	91	29,097,384	319,751
Elevate the Main Floor	16	1,740,375	108,773
Elevate the Entire Structure	140	16,851,988	120,371
Wet Flood Proof	20	1,342,792	67,140
Bi-level Homes			
Buyout	36	8,056,686	223,797
Elevate the Entire Structure	129	14,757,943	114,403
Residential Structures Without Basements			
Buyout	1	298,540	298,540
Elevate the Entire Structure	0	0	0
Total Residential			
Buyout	128	37,452,610	292,599
Elevate the Main Floor	16	1,740,375	108,773
Elevate the Entire Structure	269	31,609,931	117,509
Wet Flood Proof	20	1,342,792	67,140
Total Residential Cost of Nonstructural Flood Risk Reduction		**$72,145,708**	
Commercial Structures			
Buyout	1	1,032,000	1,032,000
Floodwall	17	3,970,938	233,585
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$5,002,938**	
Total 500-yr Plan Cost in Cass County South		**$77,148,646**	

Table 31

Fargo North 500-Year Nonstructural Flood Risk Reduction Summary Table

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	180	38,270,704	212,615
Elevate the Main Floor	406	43,171,930	106,335
Elevate the Entire Structure	9,013	1,094,293,032	121,413
Fill Basement w/ Addition	49	5,605,600	114,400
Wet Flood Proof	710	28,726,896	40,460
Bi-level Homes			
Buyout	69	10,747,440	155,760
Elevate the Entire Structure	1,237	138,007,063	111,566
Residential Structures Without Basements			
Buyout	0	0	0
Elevate the Entire Structure	22	1,596,014	72,546
Total Residential			
Buy Out	249	49,018,144	196,860
Elevate the Main Floor	406	43,171,930	106,335
Elevate the Entire Structure	10,272	1,233,896,109	120,122
Fill Basement w/ Addition	49	5,605,600	114,400
Wet Flood Proof	710	28,726,896	40,460
Total Residential Cost of Nonstructural Flood Risk Reduction		**$1,360,418,679**	
Commercial Structures			
Buyout	153	178,172,607	1,164,527
Dry Flood Proof	512	6,449,605	12,597
Fill Basement	8	314,474	39,309
Fill Basement w/ Dry FP	252	30,162,604	119,693
Fill Basement w/ Floodwall	729	273,795,033	375,576
Floodwall	1,151	162,824,484	141,463
Wet Flood Proof	10	848,320	84,832
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$652,567,127**	
Total 500-yr Plan Cost in Fargo North		**$2,012,985,806**	

Table 32

Fargo South 500-Year Nonstructural Flood Risk Reduction Summary Table

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	202	80,613,234	399,075
Elevate the Main Floor	464	52,979,872	114,181
Elevate the Entire Structure	3,394	449,339,579	132,392
Wet Flood Proof	8	488,153	61,019
Fill Basement w/ Addition	4	457,600	114,400
Bi-level Homes			
Buyout	49	13,323,026	271,898
Elevate the Entire Structure	3,704	422,671,251	114,112
Residential Structures Without Basements			
Buyout	0	0	0
Elevate the Structure	554	44,578,035	80,466
Total Residential			
Buyout	251	93,936,260	374,248
Elevate the Main Floor	464	52,979,872	114,181
Elevate the Entire Structure	7,652	916,588,865	119,784
Wet Flood Proof	8	488,153	61,019
Fill Basement w/ Addition	4	457,600	114,400
Total Residential Cost of Nonstructural Flood Risk Reduction		**$1,064,450,749**	
Commercial Structures			
Buyout	52	11,249,550	216,338
Dry Flood Proof	173	1,738,927	10,052
Fill Basement w/ Dry FP	37	6,757,140	182,625
Fill Basement w/ Floodwall	142	57,573,896	405,450
Floodwall	1,126	142,850,904	126,866
Wet Flood Proof	3	302,539	100,846
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$220,472,955**	
Total 500-yr Plan Cost in Fargo South		**$1,284,923,705**	

Table 33
Moorhead 500-Year Nonstructural Flood Risk Reduction Summary Table

Nonstructural Technique	# of Structures	Total Cost	Cost/Structure
Residential Structures With Basements			
Buyout	245	43,853,756	178,995
Elevate the Main Floor	873	122,272,857	140,061
Elevate the Entire Structure	4,246	535,063,264	126,016
Fill Basement w/ Addition	1,878	58,308,000	31,048
Bi-level Homes			
Buyout	19	3,847,862	202,519
Elevate the Entire Structure	56	7,311,775	130,567
Residential Structures Without Basements			
Buyout	1	185,850	185,850
Elevate the Entire Structure	119	11,674,236	98,103
Total Residential			
Buyout	265	47,887,468	180,707
Elevate the Main Floor	873	122,272,857	140,061
Elevate the Entire Structure	4,421	554,049,275	125,322
Fill Basement w/ Addition	1,878	58,308,000	31,048
Total Residential Cost of Nonstructural Flood Risk Reduction		**$782,517,600**	
Commercial Structures			
Total Commercial			
Buy Out	48	37,628,655	783,930
Dry	8	1,100,932	137,617
Floodwall	430	84,934,765	197,523
Relocate	13	8,659,125	666,087
Total Commercial Cost of Nonstructural Flood Risk Reduction		**$132,323,477**	
Total 500-yr Plan Cost in Moorhead		**$914,841,077**	

7.3 Project Benefits

Project benefits were calculated by St. Paul District using HEC-FDA computer model. A modified with-project condition HEC-FDA input file was created for each economic subunit and the data was run in HEC-FDA to determine damages of the project condition. The difference between the pre-project and with-project damages was then used as the project benefits. Table 34 displays these benefits and benefit to cost ratios.

Table 34
Fargo-Moorhead Metro Nonstructural Flood Risk Reduction 500-Year Plan Summary

Subunit	**500-Year Plan Total Cost**	**500-Year Plan Estimated Annual Cost**	**500-Year Plan Estimated Annual Benefits**	**500-Year Plan Benefits to Cost**	**500-Year Plan Net Benefits**
Cass County North	$71,558,839	$3,694,926	$642,940	0.17	-$3,051,986
Cass County South	$82,626,436	$4,266,399	$1,064,460	0.25	-$3,201,939
Fargo North	$2,155,913,856	$111,320,162	$48,719,156	0.44	-$62,601,006
Fargo South	$1,376,157,155	$71,057,587	$19,869,401	0.28	-$51,188,186
Moorhead	$979,797,547	$50,591,642	$4,334,295	0.09	-$46,257,347
Total 500-Year Plan	$4,666,053,833	$240,930,716	$74,630,252	0.31	-$166,300,464

8.0 Critical Facilities Stand-Alone Nonstructural Flood Risk Reduction Plan

For the Fargo-Moorhead Metro Area the 500-year floodplain would inundate approximately 33,183 structures. These structures include residential, commercial, and public structures and are summarized by economic subunit in Table 35 The water surface elevations for the 500-year project were determined from the existing conditions first generation hydraulic modeling completed by St. Paul District prior to July 2009. The structures were identified as being in the 500-year floodplain if the difference in the 500-yr water surface elevation and the ground elevation was greater than zero. It is important to note here that the structures were not selected based on 500-year floodplain delineations and the structure location.

Table 35
Residential, Commercial and Critical Facilities Summary by Economic Subunits for the 500-Year Nonstructural Flood Risk Reduction Plan

Economic Subunit	Total Residential Structures	Total Commercial Structures	Total Critical Facilities
500yr Plan			
Cass County North	293	16	1
Cass County South	433	18	1
Fargo North	11,687	2,856	23
Fargo South	8,379	1,533	9
Moorhead	7,471	497	57
Total	28,263	4,920	91

8.1 Critical Facilities Stand-Alone Nonstructural Plan Development

For the nonstructural flood risk reduction analysis of the Fargo-Moorhead Metro Area, a number of valuable datasets were obtained. The City of Fargo, City of Moorhead, Cass County, North Dakota and U.S. Army Corps of Engineers, St. Paul District provided the data for this study.

Detailed structure and economic data was provided by St. Paul District. The economic data was in the form of HEC-FDA output files and the files were the initial base data used to begin the analysis. For the economic analysis, the St. Paul District completed the assembly of ground elevations and foundation height for each structure in the Fargo-Moorhead Area. The ground elevations were extracted from LiDAR survey data and the foundation heights were determined by visually estimating the vertical distance from the ground and the foundation. The files provided occupancy type, property values, structure types, water surface elevations, ground surface elevations, and first floor elevations.

Structure GIS data was provided by St. Paul District and supplemented through the city and county GIS departments. The data was valuable to determine the spatial locations of the structures in the economic analysis. The files provided structure location, plan view area and footprint. The economic data and structure GIS data were joined together through ArcMap and used as the base data.

Hydraulic data was provided by the St. Paul District. The hydraulic model included cross sections for the Red River of the North. The elevations from the hydraulic model were used to determine the water surface elevation at each structure. The water surface elevations had already been assigned to the structures in the structure data provided from the economic analysis. The elevations were checked to the hydraulic model and found to be in good agreement.

8.2 Summary of Plan

The nonstructural flood risk reduction plan for the critical facilities was completed for five economic subunits. The subunits include Moorhead, Cass County North, Cass County South, Fargo North and Fargo South. Because of the relatively low number of structures located within these units each structure was looked at and a nonstructural flood proofing method was assigned to it. Since critical facilities are to be operational during an emergency, only the 500-year event was used in this analysis.

Nonstructural flood risk reduction techniques were assigned to the structure based on the criteria discussed in Report Sections 2.2 and 2.3. These structures and techniques are summarized in Table 36.

Table 36
Critical Facilities Stand-Alone Nonstructural Flood Risk Reduction Summary Table

Nonstructural Technique	**# of Structures**	**Total Cost**	**Cost/Structure**
Fargo North			
Relocate	3	$955,734	$318,578
Flood Wall	14	$6,956,385	$496,885
Dry	6	$1,507,641	$251,273
Fargo North Total		$9,419,760	
Fargo South			
Flood Wall	9	$13,360,122	$1,484,458
Fargo South Total		$13,360,122	
Cass County North			
Flood Wall	1	$122,820	$122,820
Cass County North Total		$122,820	
Cass County South			
Flood Wall	1	$293,246	$293,246
Cass County South Total		$293,246	
Moorhead			
Relocate	3	$287,870,337	$95,956,779
Flood Wall	51	$27,778,318	$544,673
Buyout	3	$15,662,664	$5,220,888
Moorhead Total		$331,311,319	
Total Project Cost		**$354,507,267**	

9.0 Summary of Stand-Alone Nonstructural Assessment

Three separate stand-alone nonstructural plans were assessed for the Fargo-Moorhead Metro Area. Each plan investigated the feasibility of implementing nonstructural techniques for residential, commercial, and critical facilities. None of the individual plans or any of the five economic subunits resulted in positive net benefits or a benefit to cost ratio greater than 1.0. During the nonstructural investigation there appeared to be individual structures contained within an economic subarea that resulted in an economically feasible solution. However, the analysis was based upon entire economic subunits so that project implementation would cover the entire unit and not be left to individual structures.

As a result of the nonstructural assessment, the 200-year stand-alone plan had the greatest benefit to cost ratio of 0.37. The 100-year plan had a ratio of 0.35 and the 500-year plan had a ratio of 0.31. The results for the plans are summarized in Table 37.

Table 37
Summary of Economic Analysis of Stand-Alone Nonstructural Plans

Unit	100- Year Plan Total Cost	100-Year Plan Est Annual Cost	100-Year Plan Est Annual Benefits	100-Year Plan BCR	100-Year Plan Net Benefits
Cass County North	$43,458,596	$2,243,976	$584,216	0.26	-$1,659,760
Cass County South	$56,807,340	$2,933,235	$934,175	0.32	-$1,999,060
Fargo North	$477,819,023	$24,672,086	$13,526,428	0.55	-$11,145,658
Fargo South	$715,101,326	$36,924,108	$10,746,925	0.29	-$26,177,183
Moorhead	$266,429,979	$13,757,056	$2,403,667	0.17	-$11,353,389
Total 100-Year Plan	$1,559,616,264	$80,530,461	$28,195,411	0.35	-$52,335,050

Unit	200- Year Plan Total Cost	200-Year Plan Est Annual Cost	200-Year Plan Est Annual Benefits	200-Year Plan BCR	200-Year Plan Net Benefits
Cass County North	$48,620,660	$2,688,722	$621,768	0.23	-$2,066,954
Cass County South	$61,728,963	$3,413,674	$1,019,232	0.30	-$2,394,442
Fargo North	$1,413,385,936	$78,161,680	$43,340,376	0.55	-$34,821,304
Fargo South	$1,112,335,606	$61,513,290	$17,788,660	0.29	-$43,724,630
Moorhead	$640,365,500	$35,412,863	$3,663,416	0.10	-$31,749,447
Total 200-Year Plan	$3,276,436,665	$181,190,229	$66,433,451	0.37	-$114,756,778

Unit	500-Year Plan Total Cost	500-Year Plan Est Annual Cost	500-Year Plan Est Annual Benefits	500-Year Plan BCR	500-Year Plan Net Benefits
Cass County North	$71,558,839	$3,694,926	$642,940	0.17	-$3,051,986
Cass County South	$82,626,436	$4,266,399	$1,064,460	0.25	-$3,201,939
Fargo North	$2,155,913,856	$111,320,162	$48,719,156	0.44	-$62,601,006
Fargo South	$1,376,157,155	$71,057,587	$19,869,401	0.28	-$51,188,186
Moorhead	$979,797,547	$50,591,642	$4,334,295	0.09	-$46,257,347
Total 500-Year Plan	$4,666,053,833	$240,930,716	$74,630,252	0.31	-$166,300,464

10.0 Recommendations of the Stand-Alone Nonstructural Plans

The nonstructural assessment of stand-alone plans for the 100-year, 200-year, and 500-year flood events for the Fargo-Moorhead Metro Area did not result in a project with a benefit to cost ratio greater than 1. The very large number of structures, 33,274 for the 500-year plan, the flat topography located along either side of the Red River, and the vast extent of flooding, prevented the formulation of a feasible stand-alone nonstructural plan. While the implementation of a structural project such as a diversion channel or levee system may prove to be economically feasible, it is recommended that the National Economic Development Plan utilize nonstructural techniques in support of structural measures to eliminate residual flood damages associated with the implementation of the final project.

11.0 Nonstructural Flood Risk Reduction in Support of Diversion Structures

The results of the stand-alone nonstructural assessment for the 100-year, 200-year, and 500-year flood events indicate that nonstructural mitigation measures alone are not feasible on a large scale basis (benefit cost ratio varied from 0.31 to 0.35). The extremely flat terrain, large extent of flooding, coupled with the density of residential and commercial structures was not conducive to establishing a viable nonstructural plan which would eliminate flood damages while being cost effective.

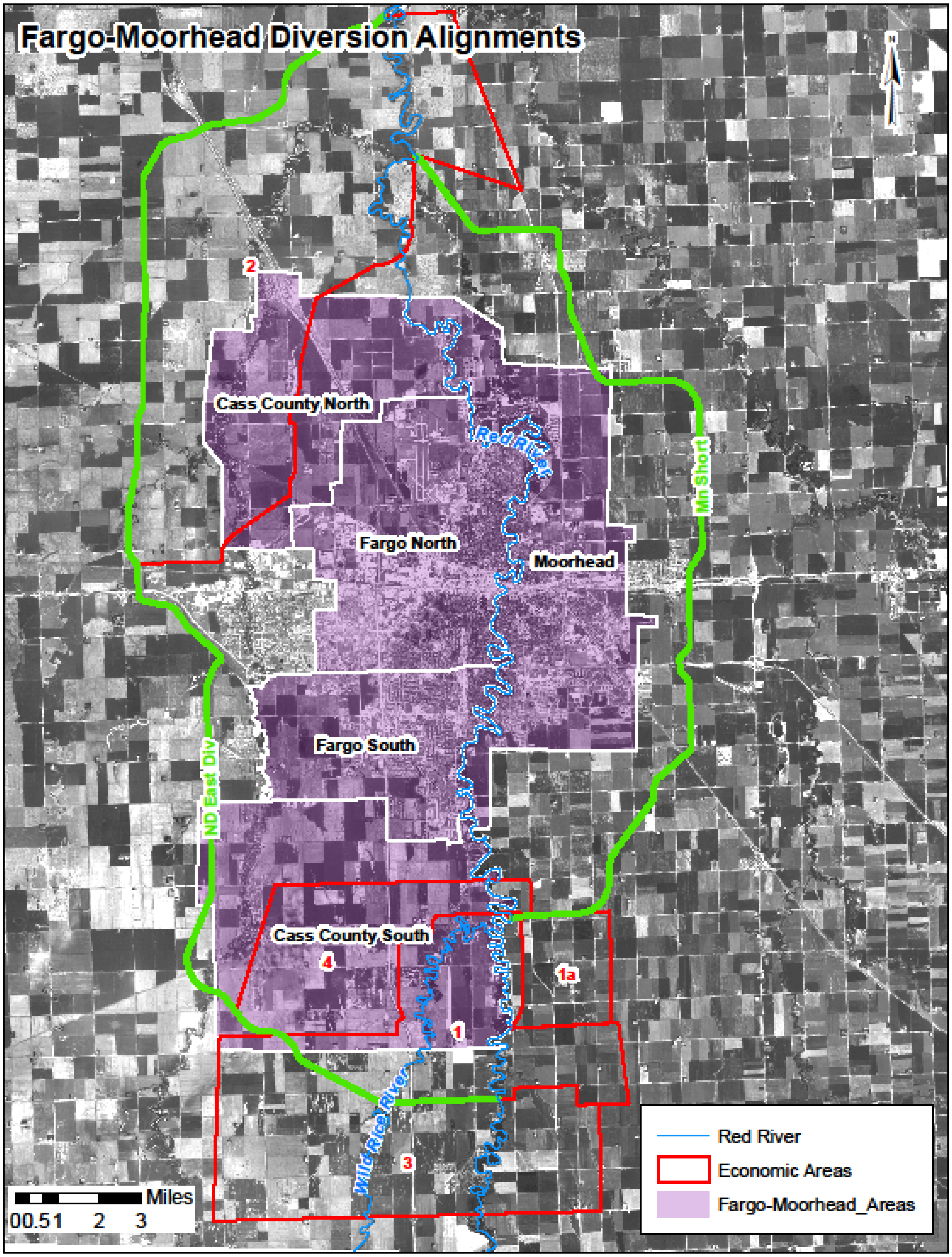
The remaining sections of this report focus on the implementation of nonstructural measures and techniques in support of several diversion channel alternatives proposed for the metropolitan area. The nonstructural measures considered would eliminate the damages associated with residual flooding which the diversion channel alternatives would not be able to effectively reduce.

11.1 Diversion Alternative Description

The diversion channel alternatives would route flood flows around the metropolitan area, thus reducing stages in the natural river channel through town. A control structure would be required on the Red River to divert flows into the diversion channel and drop structures would be necessary to allow local drainage to enter the diversion channel. Tie-back levees at the southern limits of the project would be necessary to prevent flood flows from flanking the diversion.

Numerous diversion plans were analyzed during the initial screening by the St. Paul District, including a total of four separate alignments, two in Minnesota and two in North Dakota, with various capacities. The Red River control structure allows for the maximum benefit for a given diversion channel capacity by reducing water surface elevations immediately downstream of the structure. Additionally, the control structure allows the water surface elevation upstream of the project to remain at or near natural elevation to prevent erosion-causing velocities in the Red River at the upstream end of the project. The North Dakota alignments would require additional hydraulic structures where the diversion alignments cross the Wild Rice, Sheyenne, Maple and Rush Rivers. After screening was conducted on the four separate diversion channel alignments, which are described in the following paragraphs, the two alignments shown in Figure10 were assessed by nonstructural means for additional reduction of residual flood risks.

Figure 10
Fargo-Moorhead Metro Diversion Channel Alignments



<u>Minnesota Short Alignment</u>. The Minnesota short diversion channel alignment is approximately 25 miles long, starting near the confluence of the Wild Rice and Red Rivers and ending near the confluence of Sheyenne and Red Rivers. Four separate diversion capacities were analyzed for the Minnesota diversion alignments including 20,000, 25,000, 30,000 and 35,000 cfs. The channel configuration should have a maximum depth of approximately 30 feet due to geotechnical concerns, and the channel bottom widths range from 175 to 360 feet. The Minnesota short diversion channel alignment includes 20 highway bridges and 4 railroad bridges. The flow split between the diversion channel and the Red River would be controlled by a combination of a control structure on the Red River at the south end of the project and a weir at the entrance to the diversion channel. The Minnesota Short alignment is shown in Figure 11.

<u>Minnesota Long Alignment.</u> The Minnesota long diversion channel alignment was envisioned to start approximately 3 miles south of the confluence of the Red and Wild Rice Rivers and would end at the Red River near the confluence of the Red and Sheyenne Rivers. The alignment would be approximately 29 miles long. Because this alignment begins south of the confluence of the Red and Wild Rice Rivers, an extension of the diversion channel would be required between the Red and Wild Rice Rivers. A tie-back levee would be required to extend west from the Wild Rice control structure to higher ground to prevent flanking of the diversion. The Minnesota Long alignment was screened from further assessment and not considered in the nonstructural investigation.

<u>North Dakota West Alignment.</u> The North Dakota West diversion channel alignment was envisioned to start approximately 4 miles south of the confluence of the Red and Wild Rice Rivers and extend west and north around the cities of Horace, Fargo, West Fargo, and Harwood and would end at the Red River, north of the confluence of the Red and Sheyenne Rivers near the city of Georgetown, Minnesota. The alignment would be approximately 35 miles in length. The North Dakota West alignment was screened from further assessment and not considered in the nonstructural investigation.

<u>North Dakota East Alignment.</u> The North Dakota East diversion channel alignment starts approximately 4 miles south of the confluence of the Red and Wild Rice Rivers and would use the existing Horace to West Fargo Sheyenne River Diversion corridor between Horace and I-94 after crossing the Sheyenne River. The North Dakota East alignment would be approximately 36 miles in length. This alignment was analyzed for flows of 30,000 and 35,000 cfs. The North Dakota east alignment is shown in Figure 12.

This alignment requires an extension of the diversion channel located between the Red and Wild Rice Rivers which would begin south of the confluence of the Red and Wild Rice Rivers. The tie-back levee associated with this alternative would extend east from the Red River control structure to high ground. The alignment would include 18 highway bridges and 4 railroad bridges. A combination of control structures on the Red and Wild Rice Rivers at the south end of the project, along with a weir at the entrance control the flow split between the Red and Wild Rice River channels and the diversion channel. This alignment crosses several rivers, including the Sheyenne, Maple, Lower Rush, and Upper Rush.

Figure 11
Minnesota Short Alignment

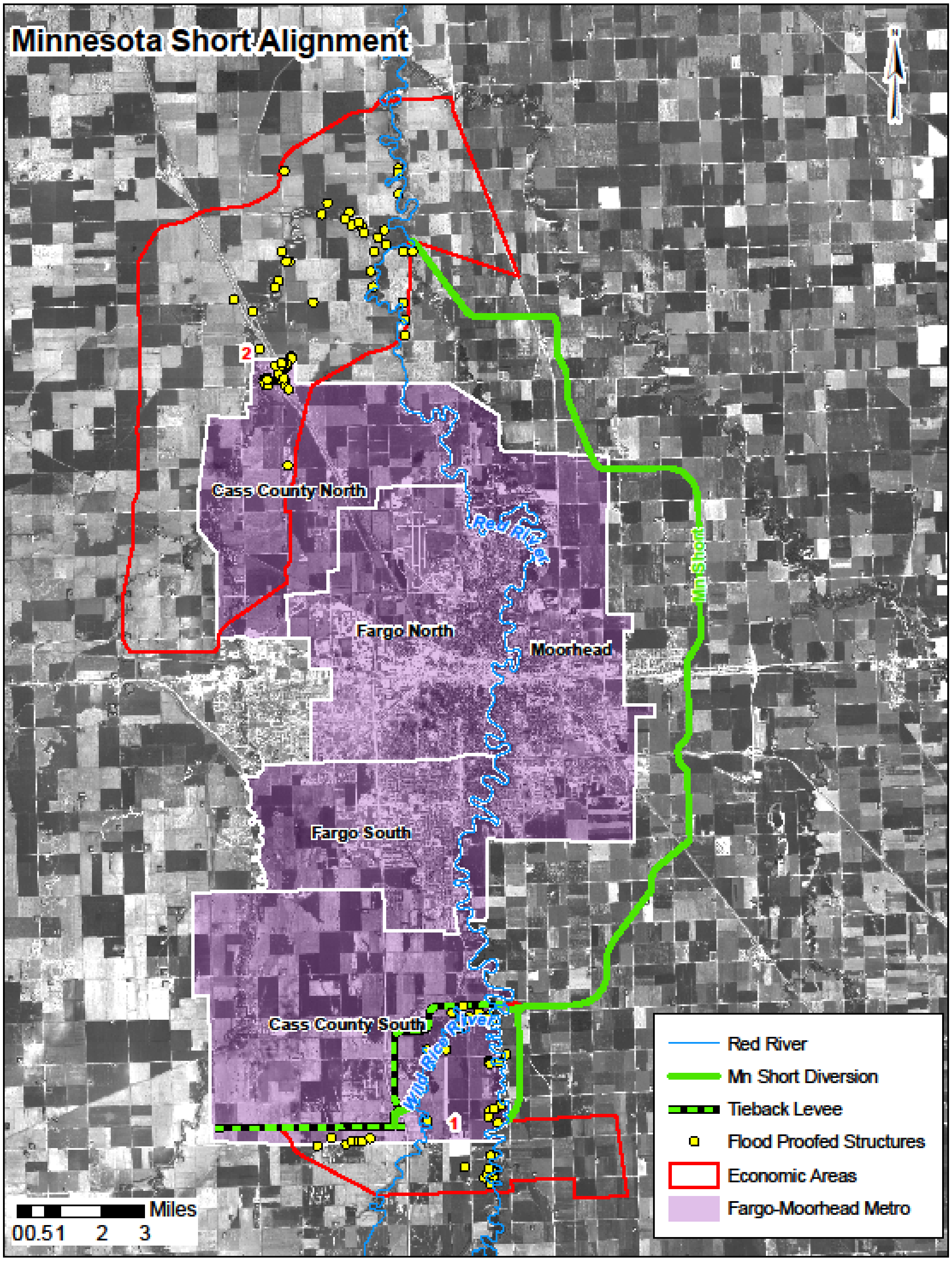
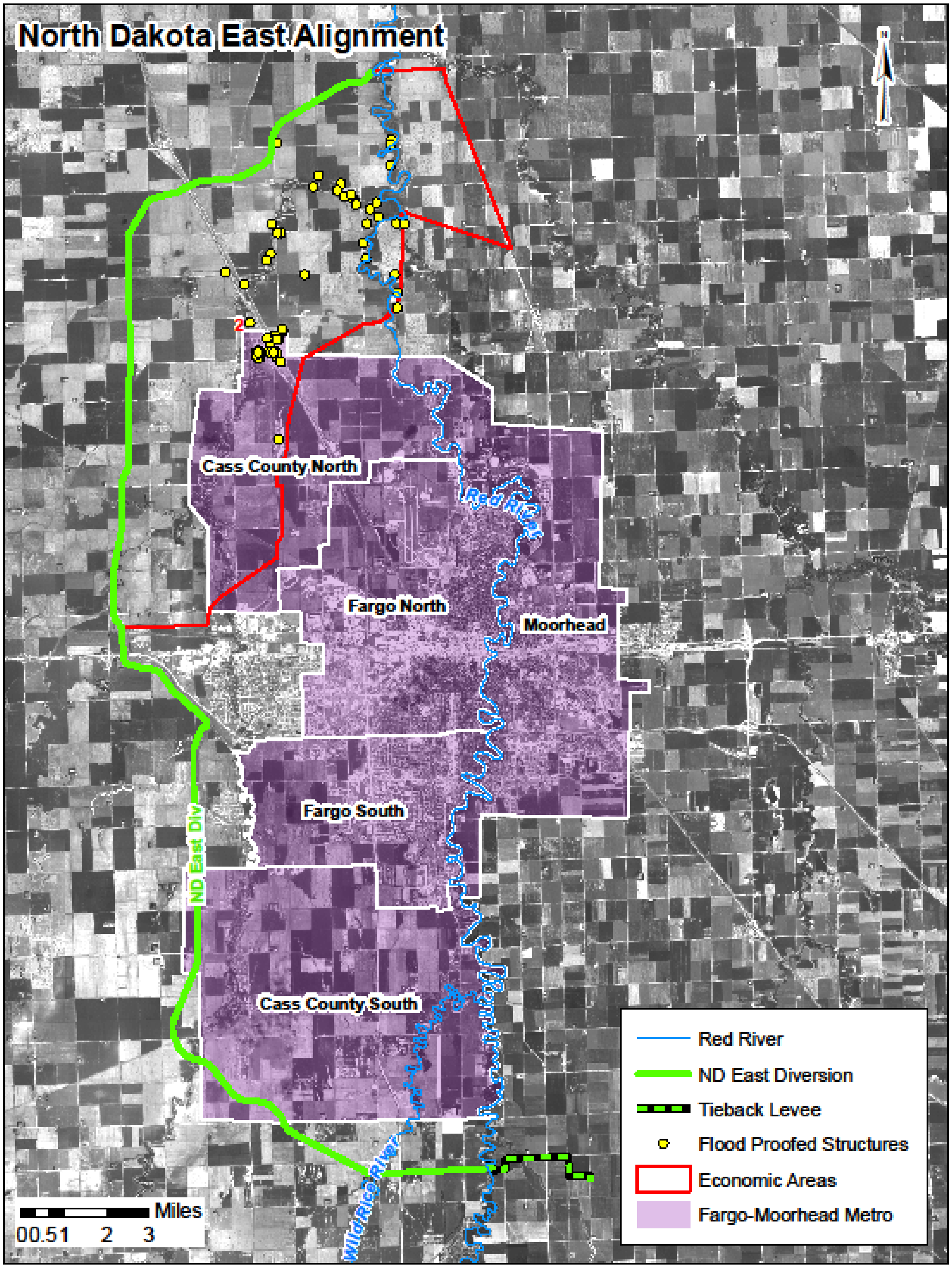


Figure 12
North Dakota East Alignment



There are six capacity alternatives associated with the diversion channel alignments, four in Minnesota and two in North Dakota. Each of the diversion channel alignments is associated with an upstream and downstream economic area containing structures which were classified as residential, commercial, or critical facility. The five economic areas assessed for the feasibility of implementing nonstructural flood damage reduction measures in support of the diversion channel alternatives are shown on Figure 10 and represented as areas 1, 1a, 2, 3, and 4. Table 38 presents the total number of structures affected by the 100-year water surface elevation and the value of total structures (residential, commercial, critical facility) for a specific capacity and diversion channel alignment.

Table 38
Summary of Total 100-Year Flood Affected Structures for Nonstructural Assessment

Diversion Alternatives (Plan)	Residential Structures	Commercial Structures	Critical Facility	Total Structures
Minnesota Short Alignment				
20,000 cfs	105	1	1	107
25,000 cfs	99	0	1	100
30,000 cfs	99	0	1	100
35,000 cfs	99	0	1	100
North Dakota East Alignment				
30,000 cfs	29	0	0	29
35,000 cfs	29	0	0	29

Diversion channel capacities of the two alignments vary between 20,000 and 45,000 cfs for the Minnesota Short diversion alignment and 30,000 and 35,000 cfs for the North Dakota East diversion alignment. Water surface profiles were determined for each diversion alternative. The profiles determined for the diversion alternatives and used in the nonstructural flood damage reduction analysis were assumed to remain equal to the without project water surface profile upstream from the diversion inlet.

The area located upstream from the diversion channel outlet (Economic Area 2) results in residual flood damages. When the water surface profiles are compared in Economic Area 2, several of the profiles are within 0.5 feet of each other regardless of the capacity of the diversion. The similarity between profiles is due to the backwater effect of the Sheyenne River and the return of the diversion flows into the Red River. To simplify computations of the nonstructural flood damage reduction analysis, water surface profiles within 0.5 feet of each other were grouped together and one water surface profile was used.

11.2 Nonstructural Techniques Used in Assessing Residential Structures.
Similar to how the residential structures were evaluated for the stand-alone nonstructural assessment, the nonstructural flood risk reduction techniques used for residential structures in support of the diversion channel alternatives includes elevating the entire structure, elevating the main floor, wet flood proofing, and permanent acquisition (buyout). Additionally, these methods were also considered in combination, such as,

filling in basements, constructing additions to compensate for lost square footage, and constructing small additions to house utilities relocated from a basement area.

11.3 Nonstructural Techniques Used in Assessing Commercial Structures.

Similar to how the commercial structures were evaluated for the stand-alone nonstructural assessment, the nonstructural flood risk reduction techniques used for commercial structures includes dry flood proofing, elevating the entire structure, constructing floodwalls, permanent acquisition (buyout), relocation of structures and wet flood proofing. These techniques were also considered in combination, in such instances where basements could be filled and combined with a dry flood proofed main floor, or filling basements and adding a floodwall.

11.4 Nonstructural Techniques Used in Assessing Critical Facilities

Similar to how the critical facility structures were evaluated for the stand-alone nonstructural assessment, these facilities were evaluated within their respective economic areas. These areas are associated with the four proposed diversion channel alignments, as shown in Figure 10, and are identified as economic areas 1, 1a, 2, 3, and 4.

Locations and information for critical facilities that were evaluated in this study were provided by Cass County, North Dakota, and the city governments of Fargo, North Dakota and Moorhead, Minnesota through the St. Paul District. Unlike the residential and commercial facilities, the critical facilities were evaluated and flood proofed for only the 0.2% annual chance flood (500-yr) event. Under Executive Order 11988, Floodplain Management, critical facilities are required to be protected to the 0.2 percent annual chance flood so they remain operational during an emergency.

12.0 Minnesota Short Alignment Nonstructural Flood Risk Reduction Plan

The 25 mile Minnesota Short diversion channel alignment was investigated for the feasible implementation of nonstructural flood risk reduction measures in the vicinity of the upstream (economic area 1) diversion channel inlet and the outlet at the confluence with the Red River (economic area 2). This is the only area located within the vicinity of the proposed diversion channel which could have residual flood impacts. The nonstructural flood risk reduction was conducted on four levels of flow for the proposed diversion channel (20,000 cfs, 25,000 cfs, 30,000 cfs, and 35,000 cfs).

12.1 20,000 CFS Plan Development

For the nonstructural flood risk reduction analysis of the 25 mile long Minnesota Short diversion channel alignment, datasets containing structure information were obtained from the City of Fargo, City of Moorhead, Cass County, and the St. Paul District. Additional detailed hydrologic data and economic information were also provided by St. Paul District. The economic data was provided in the form of HEC-FDA files which were used to develop damages and benefits for the nonstructural analysis. In order to conduct the nonstructural assessment, structure information associated with the without project and with-project 20,000 cfs discharge conditions were investigated. For the economic analysis, the St. Paul District completed the assembly of adjacent ground elevations for each structure located within the appropriate economic area. The ground elevations were extracted from Light Detection and Ranging (LiDAR) survey data and the foundation heights were determined by visually estimating the vertical distance from the ground and the foundation. The files provided to the National Flood Proofing Committee and the Omaha District contained occupancy information, property values, structure types, water surface elevations, ground surface elevations, and first floor elevations.

Structure data was spatially oriented so that specific locations of structures could be identified and linked to the economic analysis. The economic data and structure GIS data were joined together through ArcMap and used as the base data.

Elevations from the hydraulic model were used to determine the water surface elevation at each structure. The water surface elevations had already been assigned to the structures in the structure data provided from the economic analysis. Each structure was assessed in accordance with the methodology presented in Figures 8 and 9 and Report Sections 2.7 and 3.9 respectively.

12.2 25,000 CFS Plan Development

The nonstructural assessment for the 25,000 cfs capacity plan was conducted similar to the 20,000 cfs capacity plan utilizing structure data from the same datasets. With-project water surface elevations associated with the 25,000 cfs diversion channel were used for comparison purposes to the without-project conditions.

12.3 30,000 CFS Plan Development

The nonstructural assessment for the 30,000 cfs capacity plan was conducted similar to the 20,000 cfs capacity plan utilizing structure data from the same datasets. With-project water surface elevations associated with the 30,000 cfs diversion channel were used for comparison purposes to the without-project conditions

12.4 35,000 CFS Plan Development

The nonstructural assessment for the 35,000 cfs capacity plan was conducted similar to the 20,000 cfs capacity plan utilizing structure data from the same datasets. With-project water surface elevations associated with the 35,000 cfs diversion channel were used for comparison purposes to the without-project conditions.

12.5 Summary of Minnesota Short Alignment Nonstructural Plan Costs

The nonstructural flood risk reduction plan was conducted for four different flow capacities for the Minnesota Short diversion channel. Structures investigated for nonstructural mitigation were located in Economic Areas 1 and 2. Within these two economic areas the residential structures were divided into two occupancy types; residential structures with basements, and bi-level homes. The occupancy type for commercial structures and critical facilities was not subdivided for separate analysis. Nonstructural flood risk reduction techniques were assigned to the structure based on the criteria discussed in Report Chapter 2-4. The costs associated with the nonstructural techniques are summarized in Table 39. The results of the 25,000 cfs, 30,000 cfs, and 35,000 cfs plans were the same due to the similarity in the water surface profiles.

Table 39
Minnesota Short Alignment Nonstructural Flood Risk Reduction Cost Summary Table for Economic Areas 1 and 2

Nonstructural Technique Economic Area 1	**20,000 cfs Plan**		**25,000; 30,000; 35,000 cfs Plans**	
	#	Cost ($)	#	Cost ($)
Residential Structures with Basements				
Buyout	21	6,007,730	21	6,007,730
Elevate Main Floor	1	104,029	1	104,029
Elevate Entire Structure	17	2,227,793	17	2,227,793
Bi-Level Residences				
Buyout	2	1,241,596	2	1,241,596
Elevate Entire Structure	7	809,673	7	809,673
Total Nonstructural Cost	**$10,390,821**		**$10,390,821**	
Nonstructural Technique Economic Area 2	**20,000 cfs Plan**		**25,000; 30,000; 35,000 cfs Plans**	
	#	Cost ($)	#	Cost ($)
Residential Structures with Basements				
Buyout	7	1,099,642	7	1,099,642
Elevate Main Floor	22	2,423,907	22	2,420,609
Elevate Entire Structure	22	2,757,811	19	2,368,261
Bi-Level Residences				
Buyout	6	694,912	0	0
Elevate Entire Structure	0	0	3	354,019
Commercial Structures				
Flood Wall	1	92,250	0	0
Critical Facility				
Flood Wall	1	401,500	1	348,000
Total Nonstructural Cost	**$7,470,021**		**$6,590,531**	

12.5 Minnesota Short Diversion Channel Alignment Nonstructural Details

The individual structure information for the nonstructural assessment occurring in Economic Area 2 for the 20,000 cfs capacity diversion channel is shown in Table 40 and Table 41 presents the individual structure information for the nonstructural assessment occurring in Economic Area 2 for the 25,000 cfs, 30,000 cfs, and 35,000 cfs capacity alternatives.

Table 40
Minnesota Short Diversion Channel Alignment Nonstructural Details
(20,000 cfs Channel Capacity)

ID	STREET	CITY	Nonstructural Technique	100yr Cost	Annualized Cost	Benefit (x1000)	BCR	Net Benefit
400802	110 FREEDLAND DR	Harwood	Flood Wall	401,500	22,203	14.731	0.66	-7,473
400431		Reed Twp	Elevate Structure	112,079	6,198	2.000	0.32	-4,199
400431	132 BENDER LN	Harwood	Elevate Structure	112,047	6,197	2.000	0.32	-4,197
400667	438 LIND BLVD	Harwood	Elevate Structure	124,688	6,895	10.108	1.47	3,213
400687	115 RIVERSHORE DR	Harwood	Elevate Structure	112,693	6,232	2.216	0.36	-4,016
400707	106 RIVERSHORE DR	Harwood	Elevate Structure	113,534	6,278	2.095	0.33	-4,184
400754	324 RIVERTREE BLVD	Harwood	Elevate Structure	119,871	6,629	10.386	1.57	3,757
400007	17373 25 ST SE	Harwood Twp	Buy Out	129,564	7,165	12.832	1.79	5,667
400008	2551 173 AVE SE	Harwood Twp	Buy Out	113,870	6,297	10.018	1.59	3,721
400009	2623 173 AVE SE	Harwood Twp	Buy Out	147,854	8,177	10.397	1.27	2,221
400025	2769 173 AVE SE	Harwood Twp	Buy Out	123,074	6,806	4.247	0.62	-2,559
400009	2623 173 AVE SE	Harwood Twp	Buy Out	147,854	8,177	10.397	1.27	2,221
400001	17369 25 ST SE	Harwood Twp	Elevate Main Floor	112,176	6,203	14.768	2.38	8,565
400002	17135 25 ST SE	Harwood Twp	Elevate Main Floor	113,114	6,255	13.632	2.18	7,377
400004	17201 27 ST SE	Harwood Twp	Elevate Main Floor	112,661	6,230	21.166	3.40	14,936
400005	2569 172 AVE SE	Harwood Twp	Elevate Main Floor	113,566	6,280	12.193	1.94	5,913
400006	17283 26 ST SE	Harwood Twp	Elevate Main Floor	111,885	6,187	12.316	1.99	6,129
400010	2675 173 AVE SE	Harwood Twp	Elevate Main Floor	109,202	6,039	19.610	3.25	13,571
400011	2651 173 AVE SE	Harwood Twp	Elevate Main Floor	110,236	6,096	20.908	3.43	14,812
400012	17321 27 ST SE	Harwood Twp	Elevate Main Floor	108,167	5,982	16.895	2.82	10,913
400013	2618 173 AVE SE	Harwood Twp	Elevate Main Floor	111,885	6,187	28.141	4.55	21,954
400016	2631 172 1/2 ST SE	Harwood Twp	Elevate Main Floor	111,885	6,187	0.234	0.04	-5,953
400017	17254 26 ST SE	Harwood Twp	Elevate Main Floor	111,885	6,187	17.732	2.87	11,545
400018	2695 171 AVE SE	Harwood Twp	Elevate Main Floor	108,167	5,982	11.853	1.98	5,872
400020	2774 171 AVE SE	Harwood Twp	Elevate Main Floor	105,872	5,855	6.429	1.10	574
400021	2782 171 AVE SE	Harwood Twp	Elevate Main Floor	105,872	5,855	4.736	0.81	-1,119
400022	17105 27 ST SE	Harwood Twp	Elevate Main Floor	108,167	5,982	16.314	2.73	10,332
400023	2705 171 AVE SE	Harwood Twp	Elevate Main Floor	117,866	6,518	26.945	4.13	20,427
400024	2729 173 AVE SE	Harwood Twp	Elevate Main Floor	107,003	5,918	8.654	1.46	2,737
400014	2616 173 AVE SE	Harwood Twp	Elevate Main Floor	111,885	6,187	22.340	3.61	16,153
400015	2650 173 AVE SE	Harwood Twp	Elevate Main Floor	111,885	6,187	10.305	1.67	4,117
400019	16979 28 ST SE	Harwood Twp	Elevate Main Floor	105,872	5,855	9.034	1.54	3,179
400030	17164 28 ST SE	Harwood Twp	Elevate Structure	128,955	7,132	7.316	1.03	184
400047	17010 29 ST SE	Harwood Twp	Elevate Structure	126,013	6,969	2.534	0.36	-4,435
400054	2937 171 AVE SE	Harwood Twp	Elevate Structure	126,143	6,976	3.211	0.46	-3,765
400055	2941 171 AVE SE	Harwood Twp	Elevate Structure	125,043	6,915	2.558	0.37	-4,358
400757	521 DAKOTA AVE	Harwood	Flood Wall	92,250	5,102	0.019	0.00	-5,082
400631	35 LIND CIR	Harwood	Elevate Main Floor	105,484	5,833	5.277	0.90	-556
400694	101 RIVERSHORE DR	Harwood	Elevate Structure	125,528	6,942	1.881	0.27	-5,060
400559	214 MAIN ST	Harwood	Elevate Structure	127,339	7,042	1.636	0.23	-5,406
400572	516 CHAPIN DR	Harwood	Elevate Structure	120,776	6,679	0.341	0.05	-6,338
400574	512 CHAPIN DR	Harwood	Elevate Structure	124,009	6,858	1.192	0.17	-5,666
400583	511 WALLY ST	Harwood	Elevate Structure	125,625	6,947	1.264	0.18	-5,683
400586	206 TED AVE	Harwood	Elevate Structure	123,718	6,842	1.598	0.23	-5,244
400599	104 LIND BLVD	Harwood	Elevate Structure	128,212	7,090	1.550	0.22	-5,540
400603	52 LIND BLVD	Harwood	Elevate Structure	124,688	6,895	1.254	0.18	-5,641
400626	55 LIND BLVD	Harwood	Elevate Structure	128,858	7,126	1.655	0.23	-5,471
400629	43 LIND BLVD	Harwood	Elevate Structure	122,877	6,795	0.548	0.08	-6,247
400688	113 RIVERSHORE DR	Harwood	Elevate Structure	122,166	6,756	0.646	0.10	-6,110
400704	112 RIVERSHORE DR	Harwood	Elevate Structure	123,912	6,853	0.883	0.13	-5,969
400772	317 RIVERTREE BLVD	Harwood	Elevate Structure	124,753	6,899	2.086	0.30	-4,813
400781	103 TED AVE	Harwood	Elevate Structure	122,910	6,797	0.803	0.12	-5,994
400783	203 TED AVE	Harwood	Elevate Structure	124,009	6,858	1.314	0.19	-5,544
400753	320 RIVERTREE BLVD	Harwood	Elevate Structure	127,242	7,036	2.288	0.33	-4,749
13000	12109 15 ST NW	Moorhead	Elevate Structure	129,343	7,153	0.817	0.11	-6,336
13034		Moorhead	Elevate Main Floor	109,169	6,037	0.061	0.01	-5,976
13038	9999 15 ST NW	Moorhead	Elevate Structure	125,690	6,951	0.062	0.01	-6,889
13036	10615 15 ST NW	Moorhead	Buy Out	258,184	14,278	1.587	0.11	-12,691
13037	10899 15 ST NW	Moorhead	Buy Out	179,242	9,912	0.245	0.02	-9,667

Table 41
Minnesota Short Diversion Channel Alignment Nonstructural Details
(25,000 cfs, 30,000 cfs, and 35,000 cfs Channel Capacity)

ID	STREET	CITY	Nonstructural Technique	100yr Cost	Annualized Cost	Benefits (x1000)	BCR	Net Benefit
400802	110 FREEDLAND DR	Harwood	Flood Wall	348,000	19,245	10.761	0.56	-8,484
400667	438 LIND BLVD	Harwood	Elevate Structure	123,330	6,820	10.181	1.49	3,360
400707	106 RIVERSHORE DR	Harwood	Elevate Structure	112,176	6,203	2.100	0.34	-4,103
400754	324 RIVERTREE BLVD	Harwood	Elevate Structure	118,513	6,554	10.363	1.58	3,809
400007	17373 25 ST SE	Harwood Twp	Buy Out	129,564	7,165	12.832	1.79	5,667
400008	2551 173 AVE SE	Harwood Twp	Buy Out	113,870	6,297	10.018	1.59	3,721
400009	2623 173 AVE SE	Harwood Twp	Buy Out	147,854	8,177	10.397	1.27	2,220
400025	2769 173 AVE SE	Harwood Twp	Buy Out	123,074	6,806	4.205	0.62	-2,601
400009	2623 173 AVE SE	Harwood Twp	Buy Out	147,854	8,177	10.397	1.27	2,220
400001	17369 25 ST SE	Harwood Twp	Elevate Main Floor	112,176	6,203	14.768	2.38	8,565
400002	17135 25 ST SE	Harwood Twp	Elevate Main Floor	113,114	6,255	13.632	2.18	7,377
400004	17201 27 ST SE	Harwood Twp	Elevate Main Floor	112,661	6,230	21.166	3.40	14,936
400005	2569 172 AVE SE	Harwood Twp	Elevate Main Floor	113,566	6,280	12.193	1.94	5,913
400006	17283 26 ST SE	Harwood Twp	Elevate Main Floor	111,885	6,187	12.316	1.99	6,129
400010	2675 173 AVE SE	Harwood Twp	Elevate Main Floor	109,137	6,035	19.609	3.25	13,574
400011	2651 173 AVE SE	Harwood Twp	Elevate Main Floor	110,236	6,096	20.908	3.43	14,812
400012	17321 27 ST SE	Harwood Twp	Elevate Main Floor	108,070	5,976	16.894	2.83	10,918
400013	2618 173 AVE SE	Harwood Twp	Elevate Main Floor	111,885	6,187	28.141	4.55	21,954
400016	2631 172 1/2 ST SE	Harwood Twp	Elevate Main Floor	111,885	6,187	0.234	0.04	-5,953
400017	17254 26 ST SE	Harwood Twp	Elevate Main Floor	111,885	6,187	17.732	2.87	11,545
400018	2695 171 AVE SE	Harwood Twp	Elevate Main Floor	108,070	5,976	11.853	1.98	5,877
400020	2774 171 AVE SE	Harwood Twp	Elevate Main Floor	105,484	5,833	6.365	1.09	532
400021	2782 171 AVE SE	Harwood Twp	Elevate Main Floor	105,484	5,833	4.689	0.80	-1,144
400022	17105 27 ST SE	Harwood Twp	Elevate Main Floor	108,070	5,976	16.314	2.73	10,337
400023	2705 171 AVE SE	Harwood Twp	Elevate Main Floor	117,769	6,513	26.948	4.14	20,435
400024	2729 173 AVE SE	Harwood Twp	Elevate Main Floor	106,777	5,905	8.605	1.46	2,700
400014	2616 173 AVE SE	Harwood Twp	Elevate Main Floor	111,885	6,187	22.340	3.61	16,153
400015	2650 173 AVE SE	Harwood Twp	Elevate Main Floor	111,885	6,187	10.305	1.67	4,117
400019	16979 28 ST SE	Harwood Twp	Elevate Main Floor	105,484	5,833	8.944	1.53	3,111
400030	17164 28 ST SE	Harwood Twp	Elevate Structure	128,438	7,103	7.197	1.01	94
400047	17010 29 ST SE	Harwood Twp	Elevate Structure	124,753	6,899	2.460	0.36	-4,439
400054	2937 171 AVE SE	Harwood Twp	Elevate Structure	125,043	6,915	3.142	0.45	-3,773
400055	2941 171 AVE SE	Harwood Twp	Elevate Structure	123,944	6,854	1.337	0.20	-5,518
400694	101 RIVERSHORE DR	Harwood	Elevate Structure	124,171	6,867	0.977	0.14	-5,890
400559	214 MAIN ST	Harwood	Elevate Structure	125,981	6,967	1.620	0.23	-5,347
400574	512 CHAPIN DR	Harwood	Elevate Structure	122,651	6,783	0.630	0.09	-6,153
400583	511 WALLY ST	Harwood	Elevate Structure	124,268	6,872	1.231	0.18	-5,641
400586	206 TED AVE	Harwood	Elevate Structure	122,360	6,767	0.847	0.13	-5,920
400599	104 LIND BLVD	Harwood	Elevate Structure	126,854	7,015	1.512	0.22	-5,503
400603	52 LIND BLVD	Harwood	Elevate Structure	123,330	6,820	1.224	0.18	-5,597
400626	55 LIND BLVD	Harwood	Elevate Structure	127,501	7,051	1.614	0.23	-5,437
400688	113 RIVERSHORE DR	Harwood	Elevate Structure	120,808	6,681	0.661	0.10	-6,020
400704	112 RIVERSHORE DR	Harwood	Elevate Structure	122,554	6,777	0.896	0.13	-5,881
400772	317 RIVERTREE BLVD	Harwood	Elevate Structure	123,395	6,824	2.035	0.30	-4,789
400783	203 TED AVE	Harwood	Elevate Structure	122,651	6,783	1.332	0.20	-5,451
400753	320 RIVERTREE BLVD	Harwood	Elevate Structure	125,884	6,962	2.231	0.32	-4,731
400631	35 LIND CIR	Harwood	Main Floor Raise	104,126	5,758	5.439	0.94	-31,320
13000	12109 15 ST NW	Moorhead	Elevate Structure	129,246	7,148	0.817	0.11	-5,840
13034		Moorhead	Elevate Main Floor	109,072	6,032	0.061	0.01	-368
13038	9999 15 ST NW	Moorhead	Elevate Structure	124,429	6,881	0.062	0.01	-427
13036	10615 15 ST NW	Moorhead	Buy Out	258,184	14,278	1.587	0.11	-22,659
13037	10899 15 ST NW	Moorhead	Buy Out	179,242	9,912	0.245	0.02	-2,429

12.6 Summary of Minnesota Short Alignment Project Benefits

Project benefits were calculated by St. Paul District using the HEC-FDA computer program. A modified with-project condition HEC-FDA input file was created for Economic Areas 1 and 2, where the data was run in HEC-FDA to determine damages for the project condition. The difference between the pre-project and with-project damages was then used as the project benefit. Table 42displays the project benefits and associated benefit to cost ratios for the nonstructural analysis conducted on Economic Areas 1 and 2. The nonstructural assessment resulted in a feasible benefit to cost ratio for Economic Area 2 for all four capacities considered.

Table 42
Minnesota Short Alignment Nonstructural Flood Risk Reduction Benefits Summary
Economic Areas 1 and 2

Nonstructural Plan	Total Cost	Estimated Annual Cost	Estimated Annual Benefits	Plan Benefits to Cost	Plan Net Benefits
Economic Area 1					
20,000 cfs	10,390,821	574,623	260,310	0.45	-314,313
25,000 cfs	10,390,821	574,623	260,310	0.45	-314,313
30,000 cfs	10,390,821	574,623	260,310	0.45	-314,313
35,000 cfs	10,390,821	574,623	260,310	0.45	-314,313
Economic Area 2					
20,000 cfs	7,470,021	413,100	430,256	1.04	17,156
25,000 cfs	6,590,531	364,463	414,366	1.14	49,903
30,000 cfs	6,590,531	364,463	414,366	1.14	49,903
35,000 cfs	6,590,531	364,463	414,366	1.14	49,903

13.0 North Dakota East Alignment Nonstructural Flood Risk Reduction Plan

The 36 mile North Dakota East diversion channel alignment was investigated for the feasible implementation of nonstructural flood risk reduction measures in the vicinity of the downstream (Economic Area 2) diversion channel confluence with the Red River. This is the only area located within the vicinity of the proposed diversion channel which could have residual flood impacts. The nonstructural flood risk reduction was conducted on one level of flow for the proposed diversion channel (30,000 cfs).

13.1 30,000 CFS Plan Development

For the nonstructural flood risk reduction analysis of the 36 mile long North Dakota East diversion channel alignment, datasets containing structure information were obtained from the City of Fargo, City of Moorhead, Cass County, and the St. Paul District. Additional detailed hydrologic data and economic information were also provided by St. Paul District. The economic data was provided in the form of HEC-FDA files which were used to develop damages and benefits for the nonstructural analysis. In order to conduct the nonstructural assessment, structure information associated with the without project and with-project 30,000 cfs discharge conditions were investigated. For the economic analysis, the St. Paul District completed the assembly of adjacent ground elevations for each structure located within the appropriate economic area. The ground elevations were extracted from Light Detection and Ranging (LiDAR) survey data and the foundation heights were determined by visually estimating the vertical distance from the ground and the foundation. The files provided to the National Flood Proofing Committee and the

Omaha District contained occupancy information, property values, structure types, water surface elevations, ground surface elevations, and first floor elevations.

Structure data was spatially oriented so that specific locations of structures could be identified and linked to the economic analysis. The economic data and structure GIS data were joined together through ArcMap and used as the base data.
Elevations from the hydraulic model were used to determine the water surface elevation at each structure. The water surface elevations had already been assigned to the structures in the structure data provided from the economic analysis. Each structure was assessed in accordance with the methodology presented in Figures 8 and 9 Report Sections 2.7 and 3.9 respectively.

13.2 35,000 CFS Plan Development
The nonstructural assessment for the 35,000 cfs capacity plan was conducted similar to the 30,000 cfs capacity plan utilizing structure data from the same datasets. With-project water surface elevations associated with the 30,000 cfs diversion channel were used for comparison purposes to the without-project conditions.

13.3 Summary of North Dakota East Alignment Nonstructural Plan Costs
The nonstructural flood risk reduction plan was conducted for one flow capacity for the North Dakota East diversion channel. Structures investigated for nonstructural mitigation were located in economic area 2. Within this economic area the residential structures were divided into two occupancy types; residential structures with basements, and bi-level homes. There were no commercial structures and critical facilities contained within the datasets. Nonstructural flood risk reduction techniques were assigned to the structure based on the criteria discussed in Report Chapter 2-4. The costs associated with the nonstructural techniques are summarized in Table 43.

Table 43
North Dakota East Diversion Channel

Nonstructural Technique Economic Area 2	**30,000; 35,000 cfs Plans**	
	#	Cost ($)
Residential Structures with Basements		
Buyout	6	920,400
Elevate Main Floor	5	537,183
Elevate Entire Structure	17	2,149,797
Bi-Level Residences		
Elevate Entire Structure	1	115,829
Total Nonstructural Cost	**$3,723,210**	

13.4 Summary of North Dakota East Alignment Project Benefits

Project benefits were calculated by St. Paul District using HEC-FDA computer program. A modified with-project condition HEC-FDA input file was created for Economic Area 2, the only area noted for having residual structural damages, and the data was run in HEC-FDA to determine damages for the project condition. The difference between the pre-project and with-project damages was then used as the project benefits. Table 44 displays these benefits and associated benefit to cost ratios. The nonstructural assessment did not result in a feasible benefit to cost ratio for either diversion channel capacity considered.

Table 44
North Dakota East Alignment Nonstructural Flood Risk Reduction Benefits Summary for Economic Area 2

Nonstructural Plan	Total Cost	Estimated Annual Cost	Estimated Annual Benefits	Plan Benefits to Cost	Plan Net Benefits
30,000 cfs	3,723,210	205,897	132,543	0.64	-73,354
35,000 cfs	3,723,210	205,897	132,543	0.64	-73,354

14.0 Summary of Nonstructural Assessment in Support of Diversion Structures

The nonstructural assessment in support of the diversion channel alternatives was conducted in an effort to reduce residual flood damages which otherwise would not be alleviated by any of the diversion channel proposals. The only diversion plan, the Minnesota Short, resulted in a positive benefit to cost ratio for implementing nonstructural measures. The following two sections provide specific information on the results of the nonstructural assessment for the Minnesota Short diversion plan, which appears to have federal interest in implementing as part of the structural project for the Fargo-Moorhead metro area.

14.0.1 Minnesota Short 20,000 cfs Diversion Plan

The Minnesota Short 20,000 cfs Diversion Plan for Economic Area 2 resulted in a benefit to cost ratio of 1.06 and net annualized benefits of $23,239. This economic area includes a total of 57 residential structures, 1 commercial structure and 1 critical facility. The structures in this area include rural homes and structures in and around city of Harwood, North Dakota. The benefits to cost ratio for individual structures range from near 0 to 4.55. The residential structures that have the most benefit from the additional nonstructural flood risk reduction technique are those that see flood damages at the more frequent flood events.

14.0.2 Minnesota Short 25,000 cfs, 30,000 cfs, and 35,000 cfs Diversion Plans

The Minnesota Short 25,000; 30,000; and 35,000 cfs Diversion Plan Economic Area 2 resulted in a benefit to cost ratio of 1.14 and a net annualized benefit of $49,903. This economic area includes a total of 51 residential structures and 1 critical facility. The structures in this area include rural homes and structures in and around the city of Harwood, North Dakota. The benefits to cost Ratio for individual structures range from near 0 to 4.45. The residential structures that see the most benefit from the additional nonstructural flood risk reduction techniques are those that see flood damages at the more frequent flood events.

15.0 Recommendations of Nonstructural Results in Support of Diversion Structures
While the stand-alone nonstructural plans and several of the nonstructural plans in support of the diversion channel alternatives did not result in positive net benefits or benefit to cost ratios greater than 1.0, the Minnesota Short diversion plan did indicate feasible results for the nonstructural measures. From the analyses, the nonstructural measures have a benefit to cost ratio of 1.06 for the 20,000 cfs diversion channel capacity design and 1.14 for the 25,000 cfs, 30,000 cfs, and 35,000 cfs diversion channel capacities for the Minnesota Short alignment. The structures reside in Economic Area 2, which is located at the downstream end of the proposed diversion channel.

Comprehensive flood risk management and flood damage reduction may require a combination of structural and nonstructural mitigation measures to achieve the greatest level of protection against future flooding. The nonstructural assessment considered whole economic areas as described in Section 11.1. While individual structures could be presented with a greater or lesser benefit to cost ratio than what was cumulatively developed for the entire economic area, mitigation measures should be implemented for each structure across the entire economic area, in much the same way a levee would be constructed to provide a general level of protection for each and every structure located landward of the levee, whether or not adjacent structures had the same benefit to cost ratio or similar net benefits.

The nonstructural mitigation measures proposed for Economic Area 2 in support of the Minnesota Short diversion channel alternative, shown in Tables 40 and 41, consist of buyouts, elevation, and construction of flood walls. For the 20,000 cfs capacity plan there are 57 residential structures, 1 commercial structure, and 1 critical facility (ID 400802 public school). For the 25,000 to 35,000 cfs capacity plans there are 51 residential structures and 1 critical facility (ID 400802 public school). If the Minnesota Short diversion channel alternative is selected as the National Economic Development plan, it is the recommendation of the National Nonstructural Flood Proofing Committee that the nonstructural techniques emphasized for Economic Area 2 be pursued during the PED phase and implemented if the projected costs do not significantly increase.

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PART 2
SUPPLEMENTAL NONSTRUCTURAL ASSESSMENT
FOR THE
FARGO-MOORHEAD METRO FEASIBILITY STUDY

1.0 Introduction

This supplemental nonstructural assessment has been conducted in support of the U.S. Army Corps of Engineers, St Paul District [MVP], to analyze and develop a diversion channel to reduce the risk of flooding and flood damages at Fargo, North Dakota and Moorhead, Minnesota. The nonstructural assessment has been conducted by the National Nonstructural Flood Proofing Committee [NFPC] with support from the Flood Risk and Floodplain Management Section of the Omaha District.

MVP is nearing completion of a complex feasibility study which has resulted in the recommendation of a structural diversion project to eliminate flood damages within the metropolitan area. The proposed project is shown in Figure 1. This appendix functions as a complete technical document to support the nonstructural assessment of the project area defined as being located downstream from recommended feasibility project.

This appendix contains the detailed technical assessment used for investigating the feasibility of incorporating nonstructural mitigation measures within the project area, located downstream from the outlet of the recommended diversion channel. While the recommended diversion project appears to reduce the risk of flooding throughout the metropolitan area, a significant amount of structures continue to be damaged, under existing conditions, by extensive flooding along the Red River of the North.

While nonstructural measures are specific to the structure being investigated, when considered for the mitigation of flood damages, the cumulative effect is to determine a strategy for incorporating a full range of nonstructural measures which are economically feasible and will reduce the risk of flooding. Each structure assessed may require a different nonstructural measure. While this nonstructural assessment relies heavily upon an inventory of data collected in the field, each structure would be required to be inspected by a team consisting of a floodplain engineer, structural engineer, cost engineer, civil engineer, and real estate specialist in order to determine, prior to implementation, the mitigation details relative to each type of nonstructural measure employed. Because of the nature of this level of investigation, this degree of investigation was not conducted within this phase of the assessment.

Nonstructural measures require different implementation as compared to structural measures. Since each structure is owned and occupied by people, agreements must be entered into with each owner.

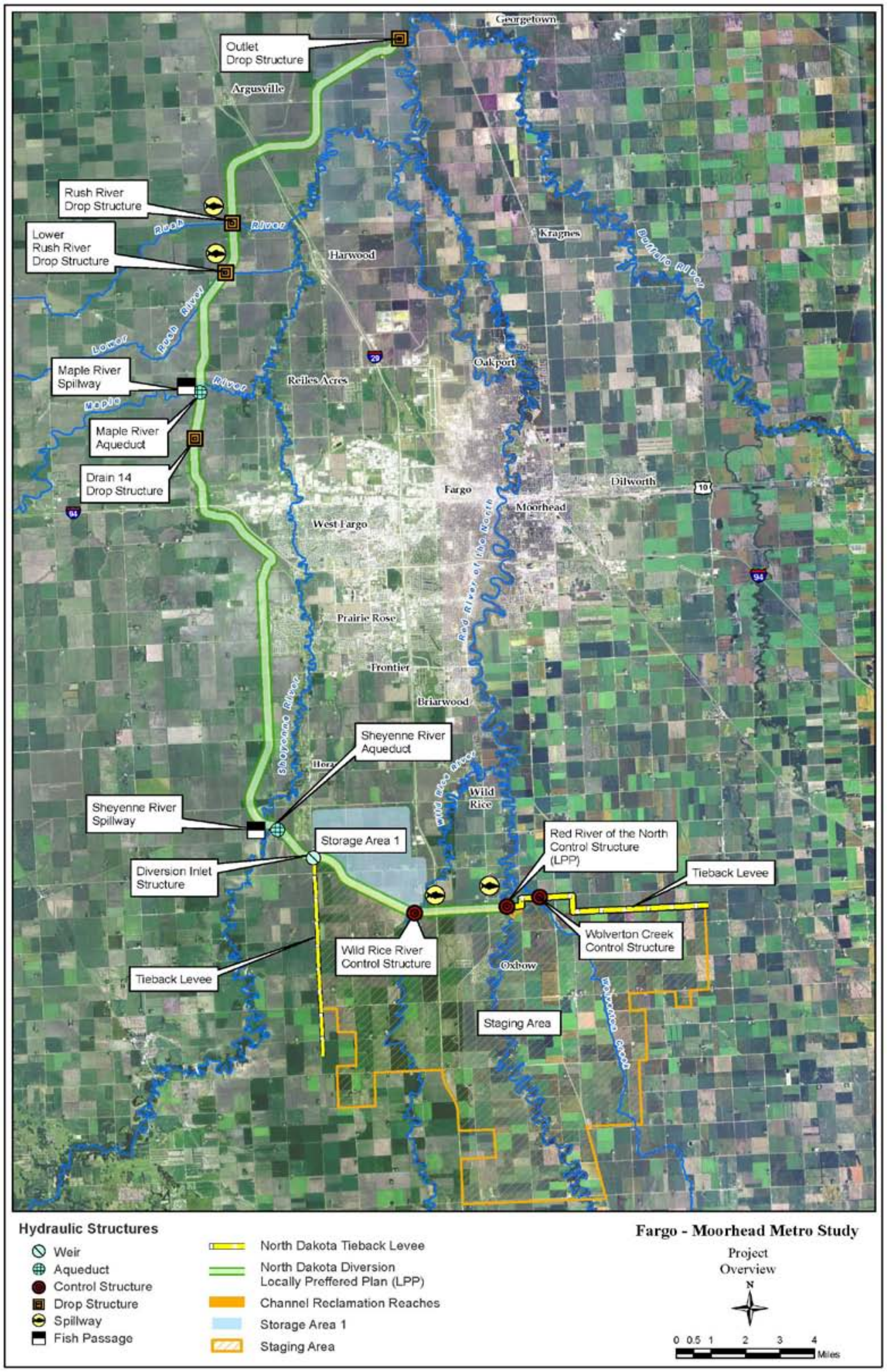


Figure 1
Recommended Diversion Channel Project Alignment

1.2 Description of Nonstructural Study Area

The nonstructural study area is shown on Figure 2.The limits of this study are from the outlet of the proposed Diversion Channel Project, downstream approximately 50 river miles.

Fargo, North Dakota and Moorhead, Minnesota are located along the banks of the Red River of the North. The Wild Rice, Sheyenne, Maple and Rush Rivers in North Dakota and the Buffalo River in Minnesota are tributaries of the Red River within the general project area. The Red River of the North flows northward approximately 453 river miles to Lake Winnipeg in Manitoba, Canada. The Fargo-Moorhead Metro area is generally very flat, having wide expanses of floodplain. The topography slopes from the south to the north.

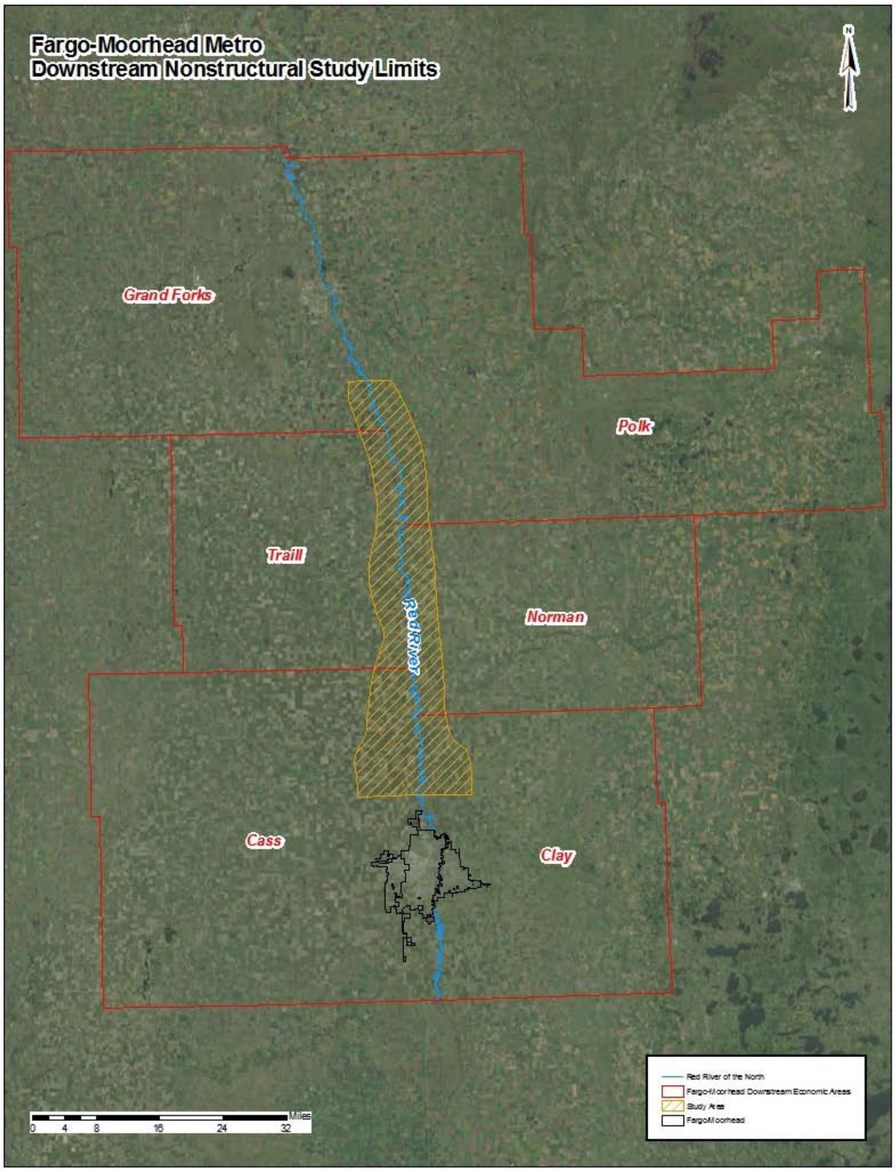


Figure 2
Nonstructural Assessment Study Location

1.3 Description of Nonstructural Assessment

For this nonstructural assessment, structure information was collected for 3,801 structures located outside of the zone of protection of the proposed Red River Diversion Channel project, shown in Figure 1.

Structure information was collected for six counties, three within Minnesota (Clay, Norman, and Polk) and three within North Dakota (Cass, Grand Forks, and Trail). Within each of these six counties the structures located within a 450-foot zone, or buffer, of the centerline of the Red River were identified, as well as all structures located within the 100-year (1% annual chance flood) delineation and the 500-year (0.2% annual chance flood) delineation. A description of the structure type investigated is shown in Table 1.

The break out of specific structure information for the individual counties is shown in Table 2. The structures located within the 450-foot buffer were considered for the buy-out option, as the depth of flooding could be significant for structures located in this area. The general study area for the nonstructural assessment is shown in Figure 2.

Table 1
Description of Structure Type

Structure Type	Structure Type Description
Commercial	Sales and transactions
Barn	Agricultural usage
Bilevel	Split level residential
Machine Shed	Agricultural Usage
Grain Bin	Agricultural usage (metal construction, cylinder)
OresWBsmt	One story residential with basement
OresWOBsmt	One story residential without basement
Silo	Agricultural usage
Hayshed	Agricultural usage
Livestock	Agricultural usage
Shop Shed	Small equipment facility
TresWBsmt	Two Story residential with basement
TresWOBsmt	Two Story residential without basement

Table 2
Inventory of Structures Located Within Six-County Assessment Area

Clay County MN				
Structure Type	**Count**	**Within 450 foot Buffer**	**Within 100-Year**	**Within 500-Year**
Commercial	3	0	3	3
Barn	6	0	1	3
Bilevel	1	0	1	1
Machine Shed	279	31	75	141
Grain Bin	289	6	40	93
OresWBsmt	73	9	27	46
OresWOBsmt	28	0	26	27
Silo	3	0	0	2
TresWBsmt	26	2	11	15
TresWOBsmt	2	0	1	2
Totals	**710**	**48**	**185**	**333**

Norman County MN				
Structure Type	**Count**	**Within 450 foot Buffer**	**Within 100-Year**	**Within 500-Year**
Commercial	3	0	1	1
Barn	10	2	6	8
Grain Bin	418	48	185	306
Hayshed	2	0	1	2
Livestock	6	0	2	4
Machine Shed	344	40	156	220
OresWBsmt	53	7	26	45
OresWOBsmt	7	0	3	3
ShopShed	4	1	3	3
Silo	2	0	0	0
SplitWBsmt	2	0	0	0
SplitWOBsmt	1	0	1	1
TresWBsmt	52	3	15	21
TresWOBsmt	1	0	0	0
Totals	**905**	**101**	**399**	**614**

Table 2 (continued)
Inventory of Structures Located Within Six-County Assessment Area

Polk County MN				
Structure Type	**Count**	**Within Floodway**	**Within 100-Year**	**Within 500-Year**
Barn	15	2	4	6
Grain Bin	176	6	20	87
Machine Shed	213	23	32	102
OresWBsmt	77	4	8	40
OresWOBsmt	2	0	0	0
Silo	1	0	0	0
TresWBsmt	1	0	0	1
Totals	**485**	**35**	**64**	**235**

Cass County ND				
Structure Type	**Count**	**Within 450 ft Buffer**	**Within 100-Year**	**Within 500-Year**
Barn	11	1	7	9
Grain Bin	284	22	121	196
Machine Shed	301	37	126	191
OresWBsmt	89	11	29	52
OresWOBsmt	2	0	1	1
Silo	5	0	3	4
TresWBsmt	13	1	1	5
Totals	**705**	**72**	**288**	**458**

Grand Forks County ND				
Structure Type	**Count**	**Within 450 ft Buffer**	**Within 100-Year**	**Within 500-Year**
Barn	8	2	1	4
Grain Bin	24	16	0	22
Machine Shed	46	11	0	25
OresWBsmt	24	5	1	9
OresWOBsmt	1	0	0	1
TresWBsmt	1	0	0	0
Totals	**104**	**34**	**2**	**61**

Table 2 (continued)
Inventory of Structures Located Within Six-County Assessment Area

Trail County ND				
Structure Type	**Count**	**Within 450 ft Buffer**	**Within 100-Year**	**Within 500-Year**
Barn	23	2	4	15
BiLevel	5	0	0	0
Commercial	2	1	0	1
Grain Bin	379	32	69	168
Machine Shed	359	40	86	194
OresWBsmt	47	3	4	26
OresWOBsmt	5	2	1	2
Shop Shed	19	1	4	9
Silo	5	2	1	4
TresWBsmt	47	3	6	22
TresWOBsmt	1	0	0	1
Totals	**892**	**87**	**179**	**441**

2.0 Nonstructural Measures Considered

This nonstructural assessment considered protection of residential, commercial, critical, and agricultural structures for a target design flood frequency of the 1% annual chance event. Each structures was analyzed based upon data collected in the field and compared to the target flood depth, where a screening process was initiated and the least cost nonstructural mitigation measure was identified.

The nonstructural measures considered during this assessment included, Elevation with Extended Foundation, Elevation with Flood Proofed Basement, Fill Basement with Main Floor Addition, Elevation on Fill, Permanent Acquisition, Nonstructural Berm, Dry Flood Proofing, and Raising Grain Bins / Silos. Each technique is discussed in detail in the following sections of this report.

2.1 Elevating Entire Structure

Elevating the entire structure requires raising the structure up from its original footings to an elevation above the design flood elevation. This technique was used on residential structures, with and without basements, and bi-level structures. To calculate the vertical distance of rise for each structure, the stage of the 1% annual chance flood event (100-year) was used and then 1.0 feet or 1.8 was added depending on the local floodplain regulations. Then the lowest level stage was subtracted. The structures with raises less than 12 feet were analyzed with this technique.

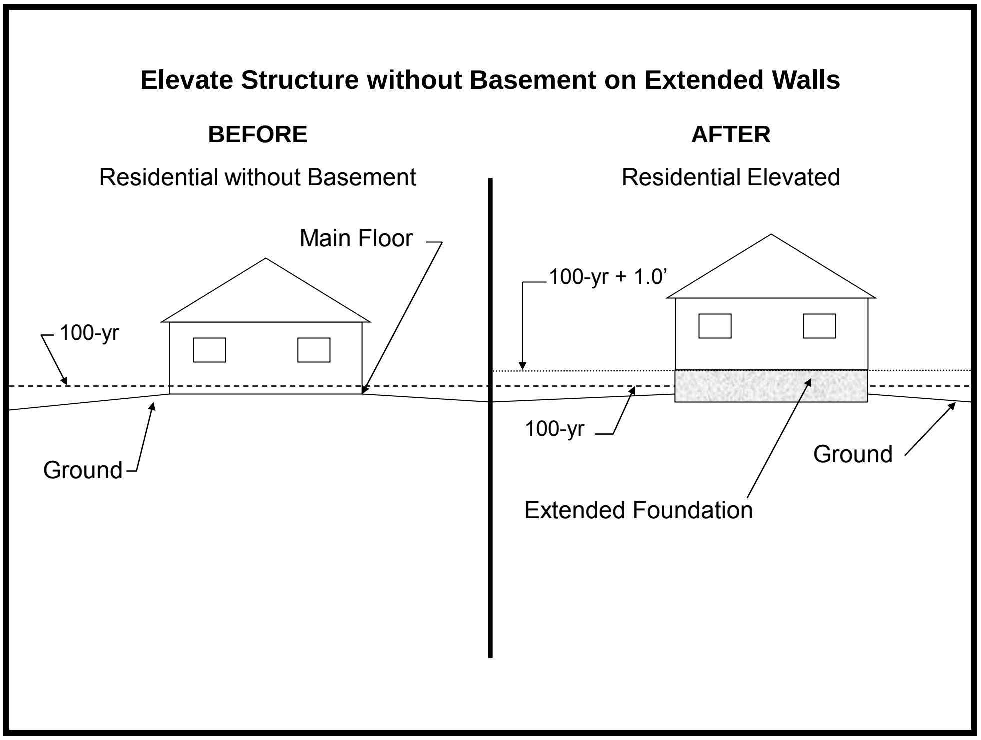
The cost to elevate the structure was figured by utilizing the equations based upon structure square footage and listed in Table 3.

Table 3
Estimated Cost to Elevate Structures

Square Foot Range	Cost to Elevate Equations
0 - 1250	1000 x (3.100 x MF_Rise + 87.5)
1250 - 1750	1000 x (3.233 x MF_Rise + 91)
1750 - Greater	1000 x (3.533 x MF_Rise + 101)

Figure 3 illustrates an example of a residential structure without a basement before and after incorporation of this nonstructural flood reduction technique.

Figure 3
Schematic of Structure without Basement



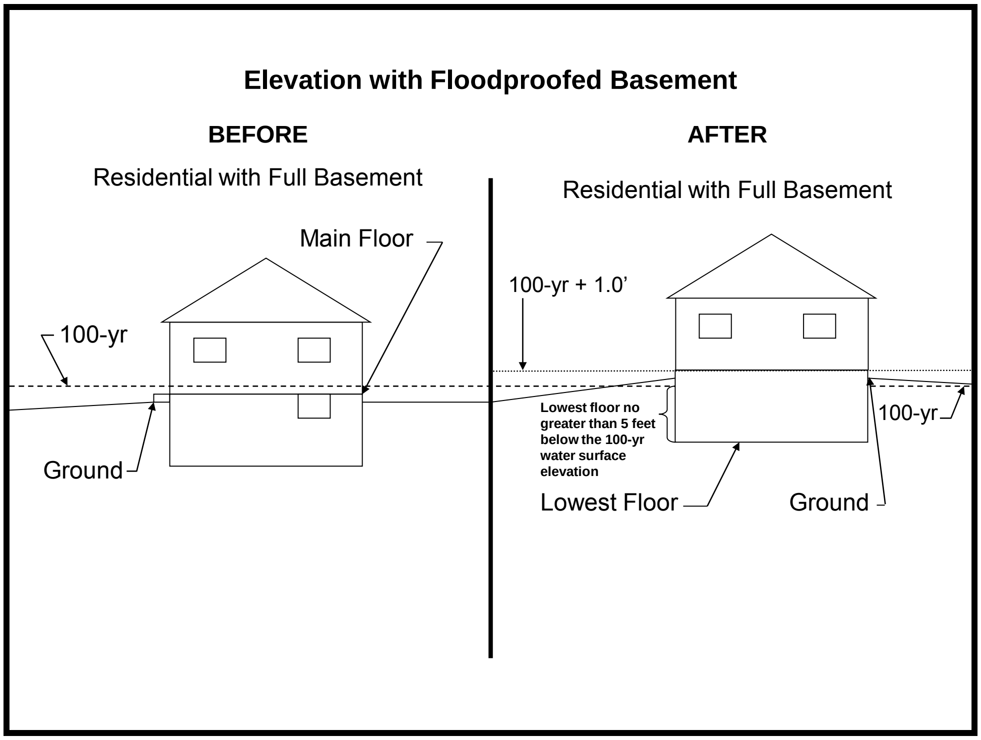
2.2 Elevation with Flood Proofed Basement

Portions of the study area, where structures contained full basements, a basement exemption may have existed. A basement exemption allows a basement to be present in a residential structure in the floodplain when the structure follows strict building codes. Elevating with dry flood proofed basement was used for residential structures where elevating the basement level up would be greater than 12 feet. For these structures, the main level was elevated above the design elevation and the new basement would be constructed following the flood proofing guidelines. The same cost estimating equations were used based on the vertical distance of elevations in Table 3, which are repeated in Table 4. Additional masonry costs may be required for determining the overall cost of the flood proofed basement. An example of this technique is shown in Figure 4 for a residential structure with a basement for the before and after conditions.

Table 4
Estimated Cost to Elevate Structures

Square Foot Range	Cost to Elevate Equations
0 - 1250	1000 x (3.100 x MF_Rise + 87.5)
1250 - 1750	1000 x (3.233 x MF_Rise + 91)
1750 - Greater	1000 x (3.533 x MF_Rise + 101)

Figure 4
Schematic of Elevated Structure with Flood Proofed Basement



2.3 Fill Basement with Main Floor Addition

Filling in the basement was an option for structures experiencing a design flood depth below the main floor elevation. The basement was removed by filling it with clean sand or fill material and capping it with concrete. The area of the structure was provided by the St. Paul District. To compensate for the lost basement area, the owner of the structure was either paid for the loss of the basement, or if feasible, an addition was built above the design event. The size of the addition was based on 75% of the total area of a finished basement and 50% of the total area of an unfinished basement. Cost estimates for the fill and the loss of the basement is summarized in Table 5. Cost estimates for the addition is summarized in Table 6. Figure 5 is a simple example of filling a basement and adding an addition to the residence.

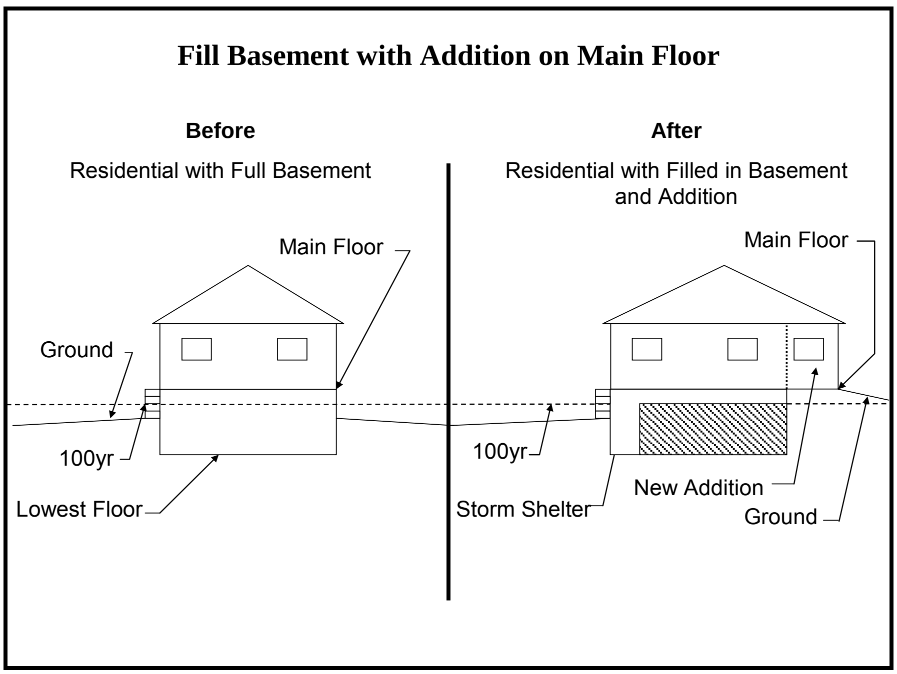
Table 5
Cost Estimating Parameters for Filling Basements for Residential Structures

Item:	Cost/Units	Quantity
Sand	$1.30/Cubic Foot	Area x 8 ft
Lost Square Footage (Unfinished)	13% of Structure Value	
Lost Square Footage (Finished)	37.5% of Structure Value	

Table 6
Cost for Addition to Residential Structures

Size	100 Square Feet	500 Square Feet	750 Square Feet	1000 Square Feet	1500 Square Feet
Cost	$21,000	$95,000	$134,100	$171,700	$247,300

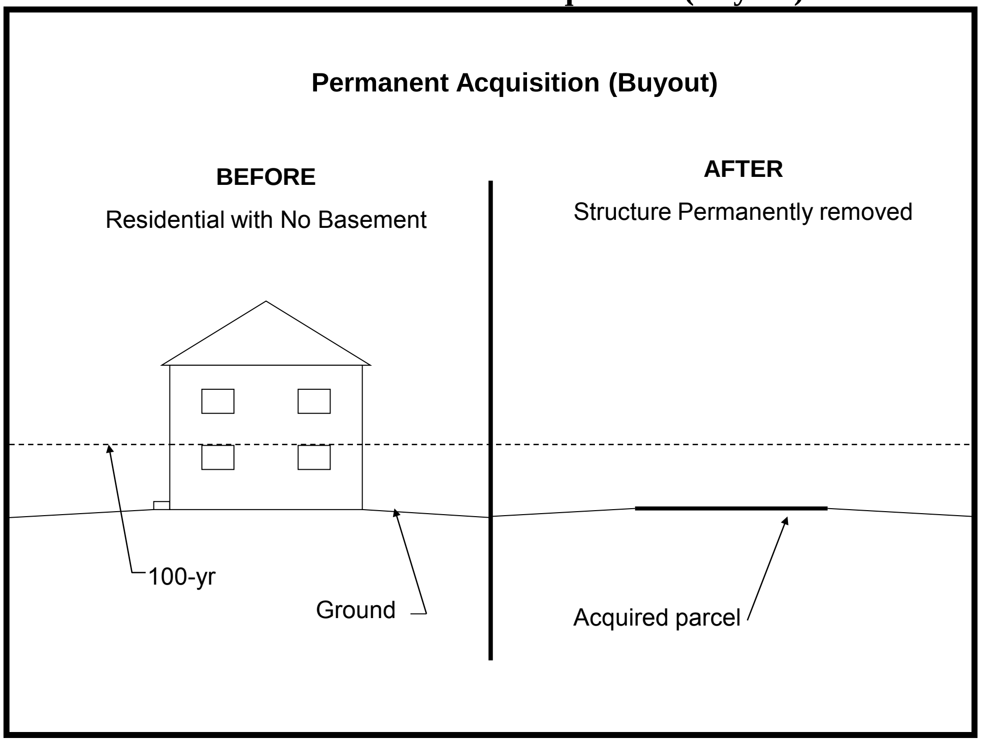
Figure 5
Schematic of Structure with Basement Filled in and Addition on Main Floor



2.4 Permanent Acquisition (Buyout)

Buyout of residential structures requires purchasing the structure and the land and either demolishing the structure or relocating it to a place that is out of the floodplain. This nonstructural method is applied to structures that are either located within the regulatory floodway, fall within a predetermined buffer zone of the river (450 foot buffer for the Red River of the North), or had a depth of flooding on the structure greater than 12 feet. Costs for this estimate were figured by taking the structure value plus the land value, which were provided by St. Paul District, and multiplying that figure by a multiplier of 1.18. Figure 6 illustrates a simple schematic where an acquisition is implemented.

Figure 6
Schematic of Permanent Acquisition (Buyout)



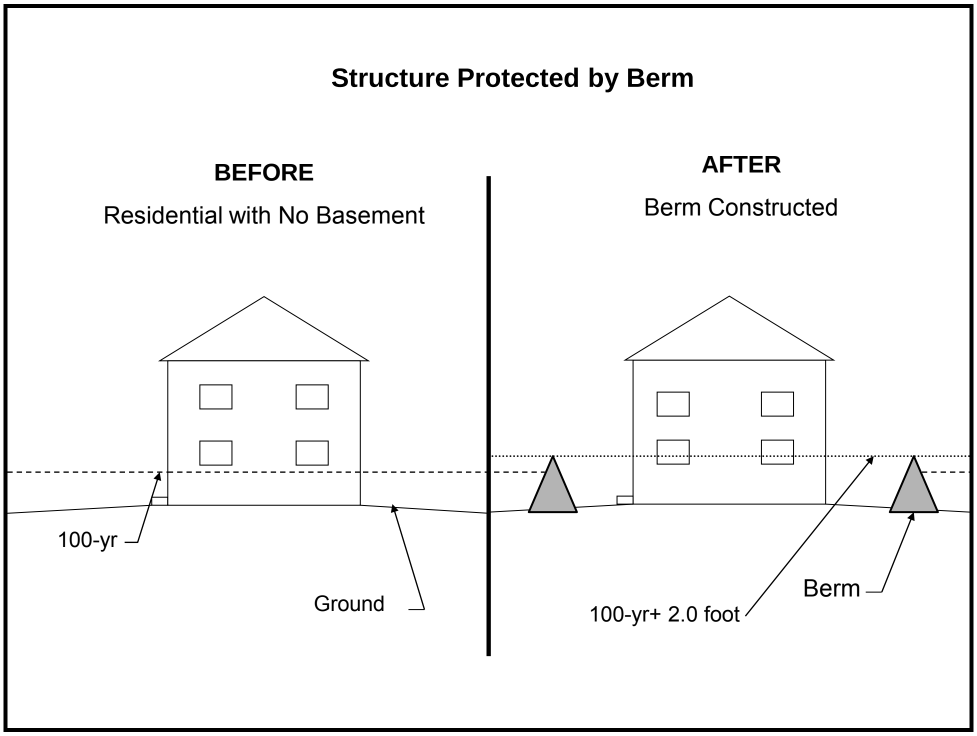
2.5 Nonstructural Berm

Nonstructural berms consist of compacted soil material placed around structures to prevent damages from flooding. For this assessment, the berms were constructed to a height of 2-foot above the design flood elevation, with a 6-foot top width, and 2.5 horizontal to 1 vertical side slopes. In some instances an existing berm was already in place and costs were considered for raising the existing berm to meet the design flood height.

Berm construction, whether to a level of protection for achieving levee accreditation through the Federal Emergency Management Agency [FEMA], as referenced in Title 44 CFR 65.10, or for personal protection preferences should be operated, maintained and repaired annually. The berm owner should conduct annual inspections and ensure closures and pumps are in good working order. As with other nonstructural measures, the NFPC advocates protecting individual structures or small groups of structures with berms, while maintaining enrollment in the National Flood Insurance Program.

For this nonstructural technique, a cost of $7.96 per cubic yard was utilized. Other costs associated with berms were for closures, pumps, seeding and maintenance. Figure 7 provides a schematic of the use of an earthen berm to protect a structure.

Figure 7
Schematic of Nonstructural Berm



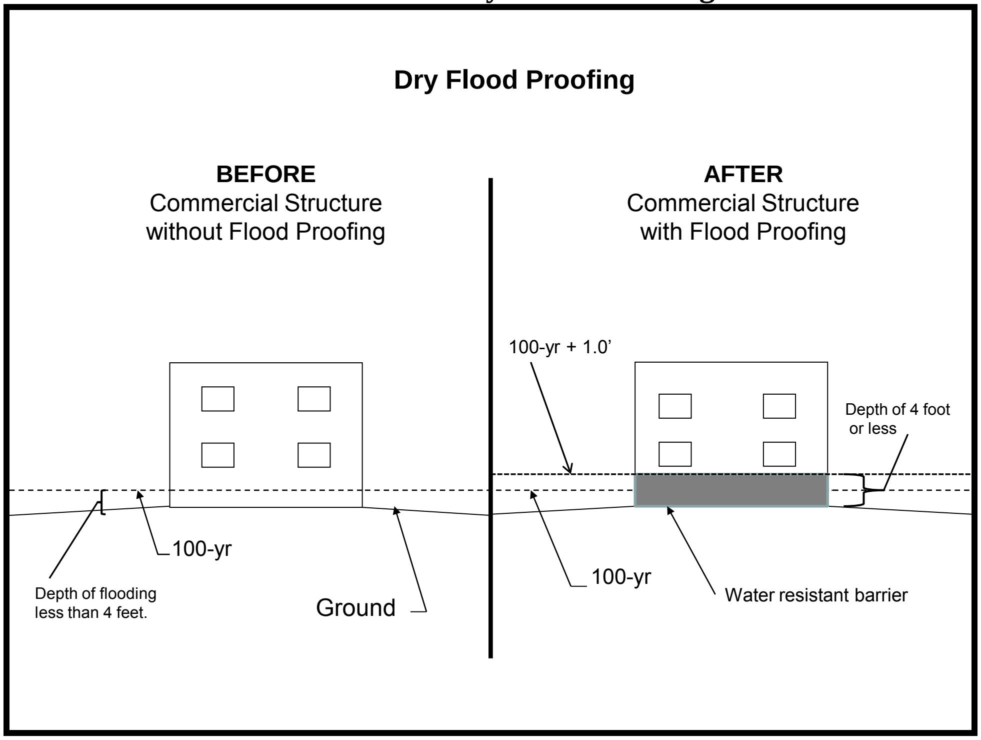
2.6 Dry Flood Proofing

Dry flood proofing for commercial structures involves applying a water resistant sealant around the structure to prevent flood water from entering. Doorways and windows are sealed with flood shields or by similar method. Cost estimates were developed for structures without basements and design flood depths of 4 feet or less. The costs used in the estimate are summarized in Table 7. The outside perimeter of a structure was determined by the building footprint shape file provided by MVP. A schematic of the dry flood proofing technique is shown in Figure 8.

Table 7
Cost Estimating Parameters for Dry Flood Proofing Commercial Structures

Item:	Cost/unit	Quantity
Spray-on Cement (1/8 inch)	$5.00/feet squared	Perimeter x Flood Depth
Asphalt (2 Coats below grade)	$2.00/feet squared	Perimeter x Flood Depth
Periphery Drainage	$35.00/feet	Perimeter
Flood Shields (metal)	$110 Each	2 (used as estimate)

Figure 8
Schematic of Dry Flood Proofing

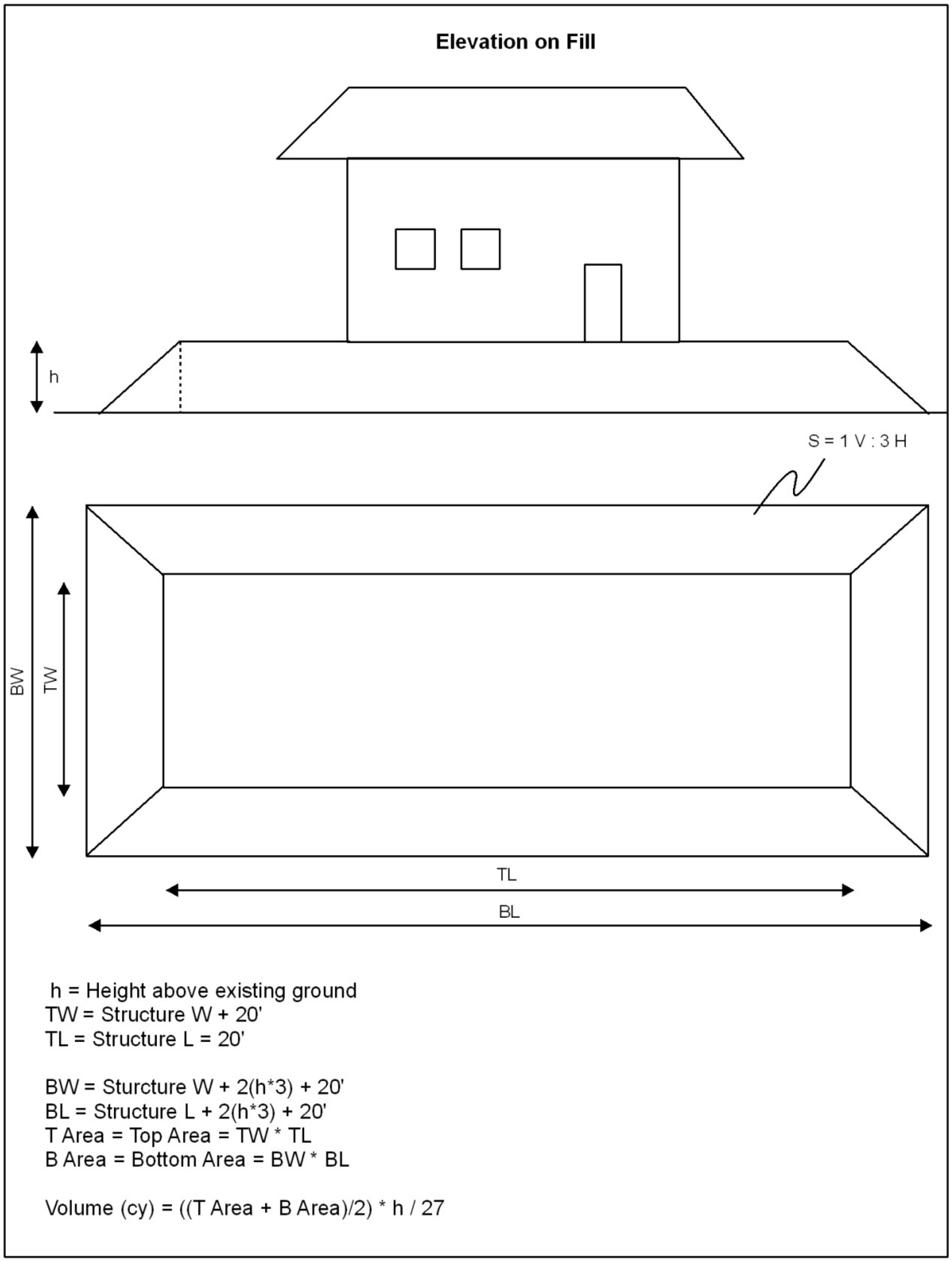


2.7 Elevation on Fill

Elevating a structure on fill material requires raising the entire structure up from its original footings to an elevation above the designated design flood elevation. This technique generally works well in rural areas, where the size of the site is not constricted. For commercial structures, elevating the entire structure was not considered as a primary technique of nonstructural flood risk reduction. This was due to the general large area required for fill placement when compared to residential construction and construction materials of most commercial buildings. Costs for elevating a structure on fill was set at $7.96 per cubic yard for the fill material only.

The height of the fill is placed at one foot above the 1% annual chance flood elevation and the side slopes are set at 3 feet horizontal to 1 foot vertical. The design elevation of the fill will be extended 10 feet from the outside of the structure. A schematic of this technique is shown in Figure 9. Equations for determining the total amount of fill material is also shown in this figure. Additional costs would be associated with temporarily elevating and moving the structure away from the existing site and then placing it onto the berm material.

Figure 9
Schematic of Elevation on Fill



2.8 Grain Bin / Silo Elevation

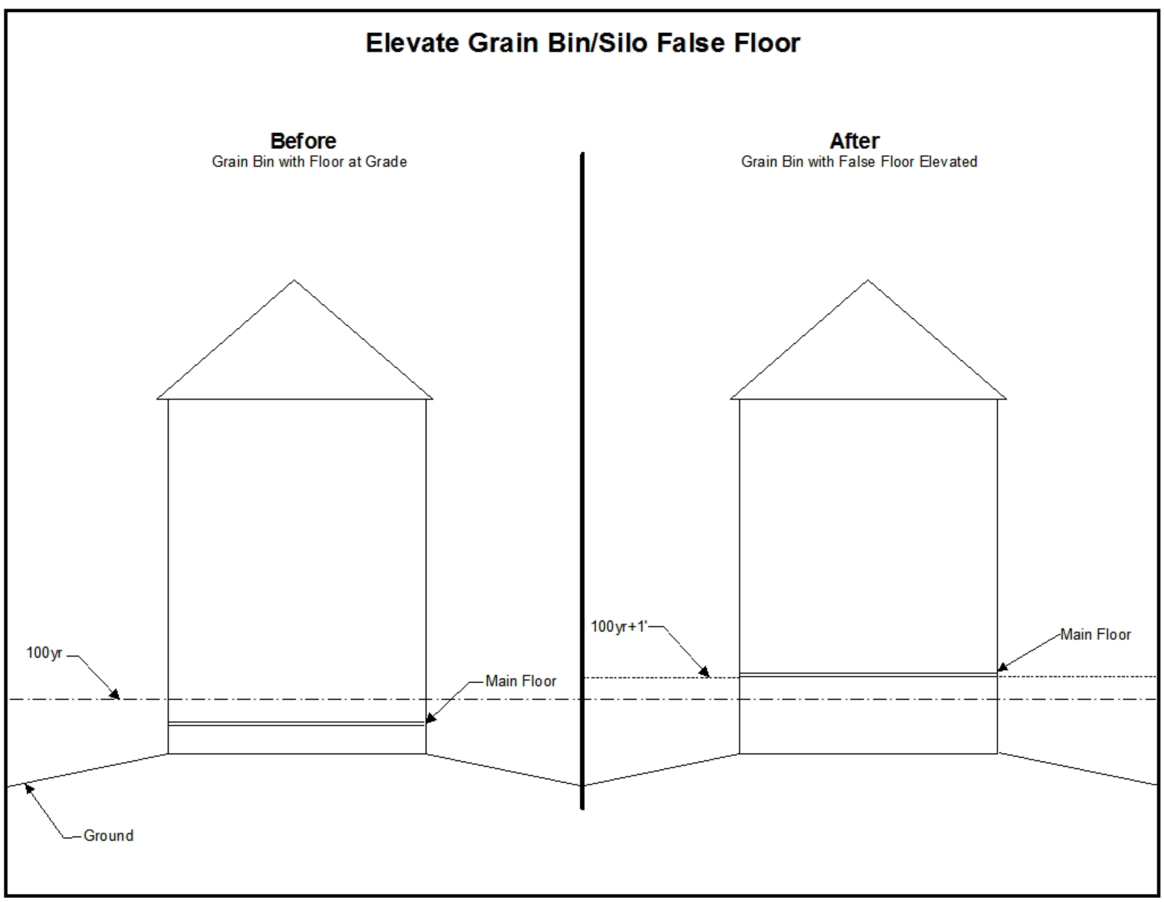
This assessment was conducted in a predominantly rural area, where agriculture was the leading industry. Within this area, numerous grain bins and silos exist. Nonstructural mitigation measures were determined for 439 bins or silos. While each of these agricultural structures is typically placed at grade, the lower elevation where the grain resides is located several feet above the adjacent grade. Even with the floor being elevated, the depth of flooding can cause significant damage to the content, which in turn could adversely impact the structure. Table 8 provides the parameters used in costing out this technique.

Table 8
Cost Estimating Parameters for Elevating Grain Bins/Silos

Bin/Silo Diameter Range (ft)	Cost to Elevate Barns
10 - 16	201x[0.6075 x [ElevHeight] + 29.853]
20 - 28	452x[0.6075x [ElevHeight] + 19.917]
32 - 40	1018x[0.6075 x [ElevHeight] + 21.613]

In order to effectively reduce flood damages, the main floor of the bin/silo is elevated to one foot above the 1% annual chance flood elevation. This technique is illustrated in Figure 10.

Figure 10
Schematic of Elevation of Grain Bins/Silos



2.9 Elevation and Wet Flood Proofing of Barns and Machine Sheds

Numerous barns and machine sheds of various sizes were also identified within the study area. All of these type structures were identified as being associated with the agricultural industry and were assessed according to their size. The parameters used to develop the costs for these structures are shown in Tables 9, 10, and 11.

Table 9
Cost Estimating Parameters for Elevating Barns

Square Foot Range	Cost to Elevate Barns
0 - 1125	750 x [0.61x[ElevHeight] + 14.52
1126 - 1875	1500 x [0.605x[ElevHeight] + 11.87
1876 - 4000	2250 x [0.6075x[ElevHeight] + 10.973
4001 - Greater	Site Specific Assessment

Table 10
Cost Estimating Parameters for Elevating Machine Sheds

Square Foot Range	Cost to Elevate Machine Sheds
0 - 3750	2500*[0.6075 * [EleHt] + 9.3333]
3750 - 6250	5000*[0.6075 * [EleHt] + 7.9967]
6250 - 10000	7500*[0.6075 * [EleHt] + 7.5333]
10000 - Greater	Site Specific Assessment

Table 11
Cost Estimating Parameters for Wet Flood Proofing Barns and Machine Sheds

Item	Cost/unit	Quantity
Removing Flood Damageable Materials	$3,900	1
Flood Vents	$472 each	Based on Area

3.0 Nonstructural Flood Risk Reduction Flow Charts

The assessment of over 3,800 structures for nonstructural mitigation purposes could be very time consuming and expensive, if a process were not developed for expediting the investigation. For this assessment, it was determined that a target design flood event equating to the 1% annual chance flood event (100-year) along the Red River of the North would be utilized. Each structure for which data had been collected in the field was compared to the target depth of flooding, from which a decision as to the most technically adequate, cost effective, and implementable nonstructural technique was determined.

In order to process all of the structures several flow charts were developed. A set of three flow charts are shown in Tables 12, 13, and 14. One flow chart focuses on the nonstructural technique decision process for residential structures, while another flow chart focuses on the nonstructural technique decision process for commercial structures, and the third flow chart focuses specifically on the implementation of earthen berms. Structures such as barns and machine sheds utilized specific techniques for elevation and wet flood proofing.

Table 12
Nonstructural Residential Structure Technique Flow Chart

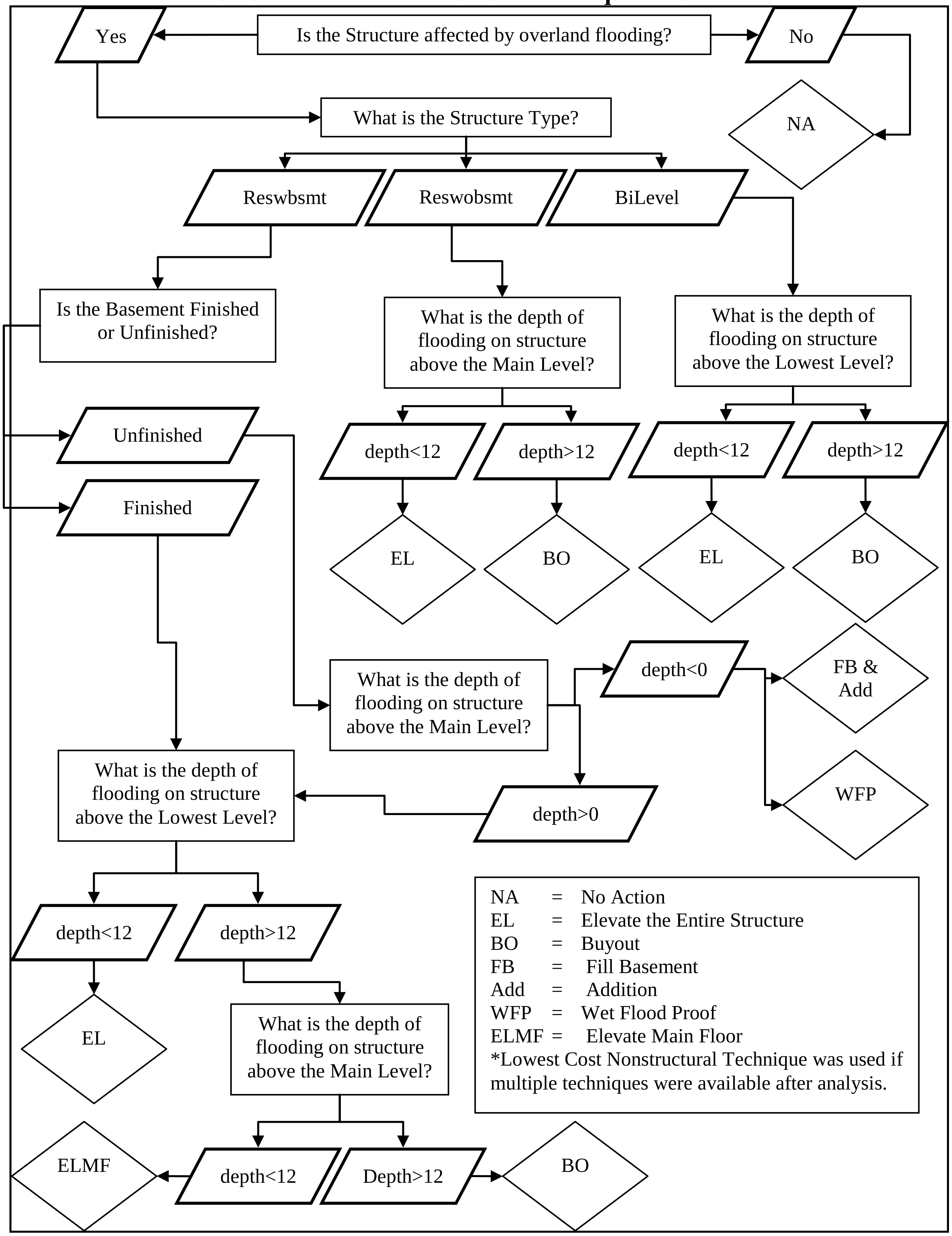


Table 13
Nonstructural Commercial Structure Technique Flow Chart

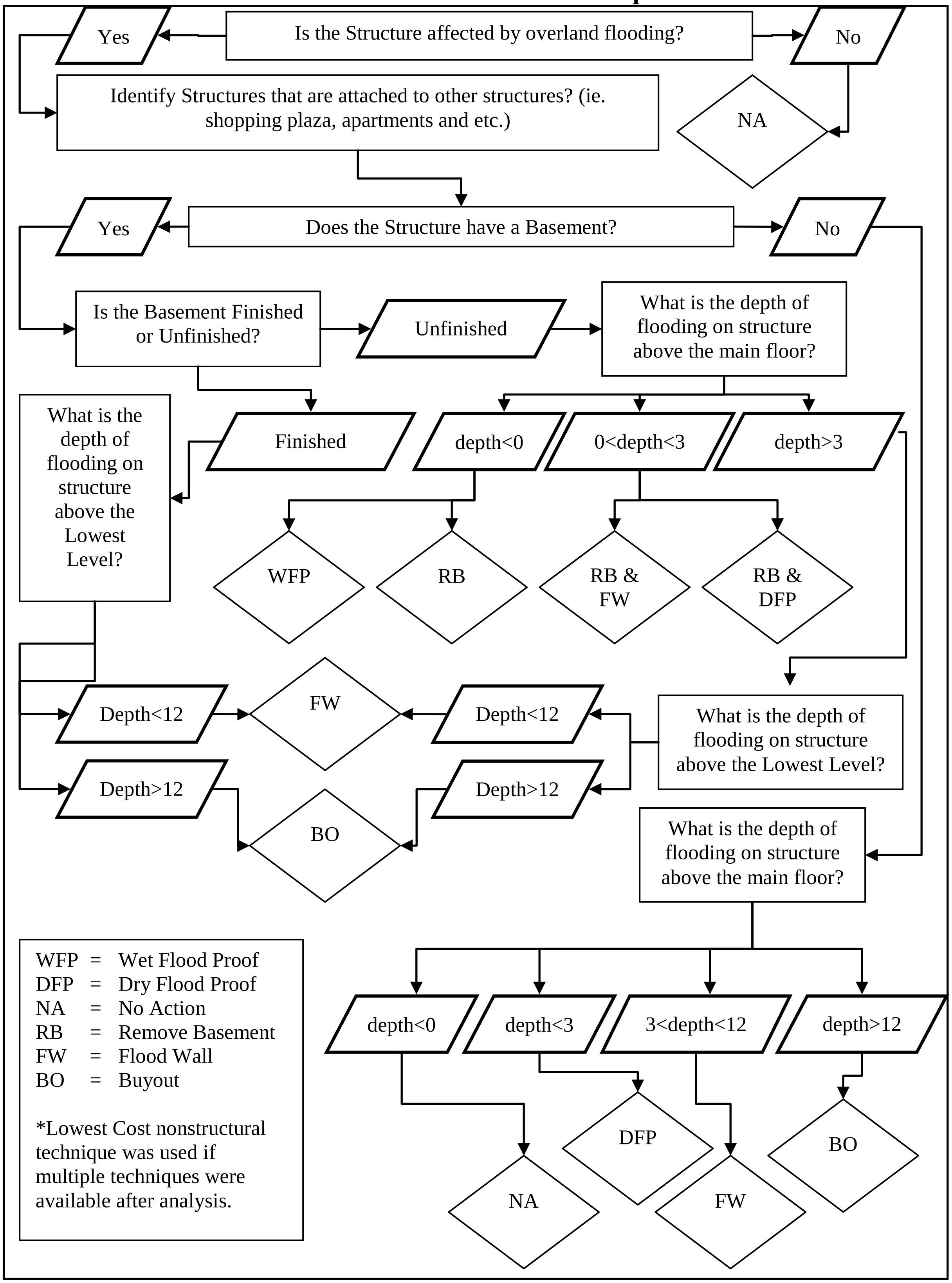
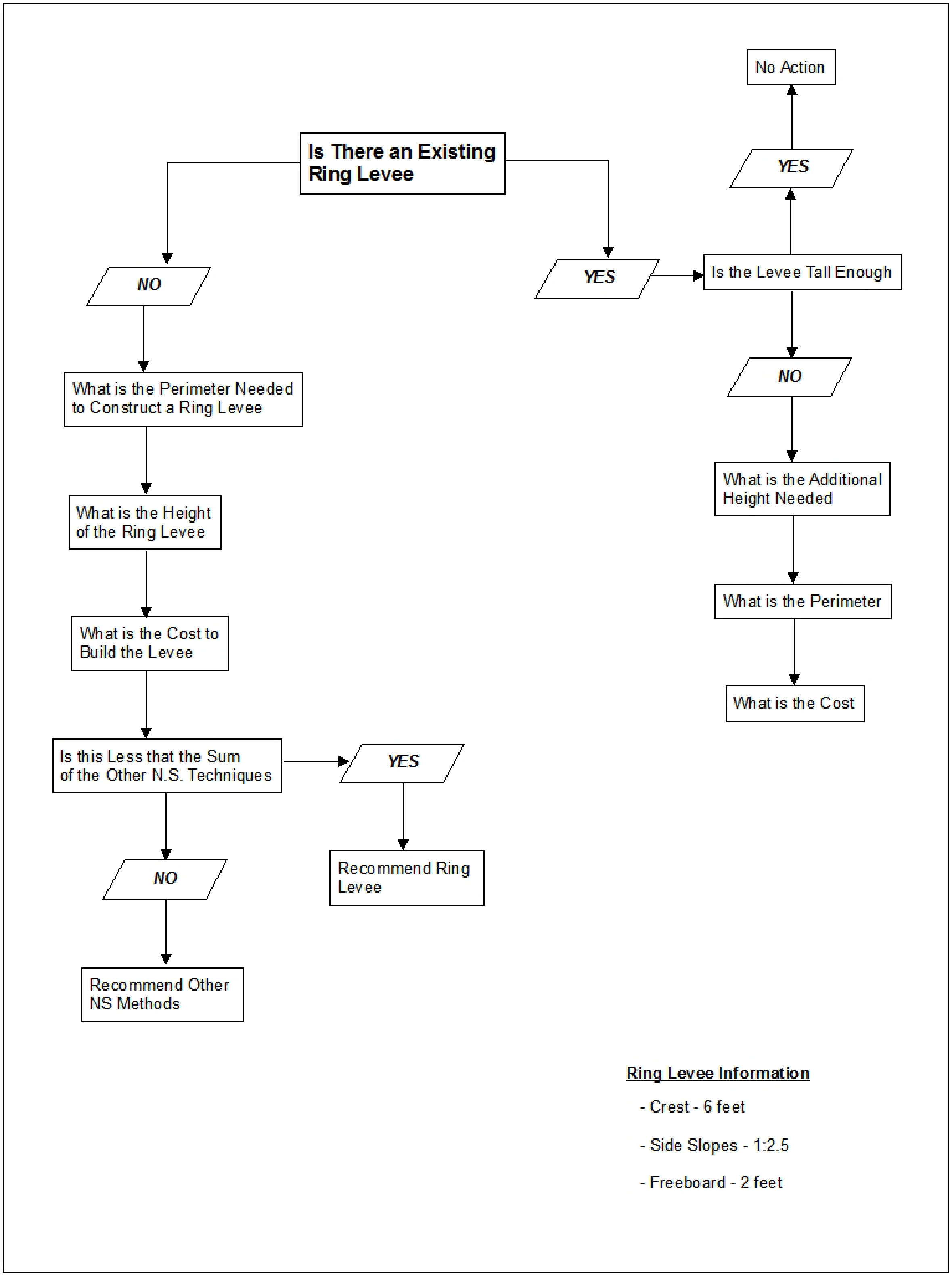


Table 14
Nonstructural Berm Selection Flow Chart



4.0 Nonstructural Plan for North Dakota Structures

For the Fargo-Moorhead Metro Downstream Area, North Dakota Subunit, the 100-year floodplain would inundate approximately 466 structures. These structures include residential and agricultural structures and are summarized in Table 15. The water surface elevations for the 100-year project were determined from the existing conditions, phase 3 hydraulic modeling, completed by MVP. The structures were identified as being in the 100-year floodplain if the difference in the 100-year water surface elevation and the ground elevation was greater than zero. It is important to note here that the structures were not selected based on 100-year floodplain delineations and the structure location within that delineation.

Table 15
Structures Considered for North Dakota Downstream Nonstructural Plan

Economic Subunit	Residential Structures	Commercial Structures	Critical Facilities	Agricultural Structures
ND 100-Year Plan				
Cass County	31	0	0	254
Trail County	15	0	0	164
Grand Forks County	1	0	0	1
Total	47	0	0	419

4.1 North Dakota Plan Development

For the nonstructural flood risk reduction analysis Downstream of the Fargo-Moorhead Metro Area, a number of valuable datasets were obtained. Cass, Trail, and Grand Forks Counties in North Dakota and MVP provided the data for this plan development.

Detailed structure and economic data was provided by MVP. The economic data was in the form of HEC-FDA output files and the files were the initial base data used to begin the analysis. For the economic analysis, MVP completed the assembly of ground elevations and foundation height for each structure Downstream of the Fargo-Moorhead Area. The ground elevations were extracted from Light Detection and Ranging (LiDAR) survey data and the foundation heights were determined by visually estimating the vertical distance from the ground and the foundation. The files provided occupancy type, property values, structure types, water surface elevations, ground surface elevations, and first floor elevations.

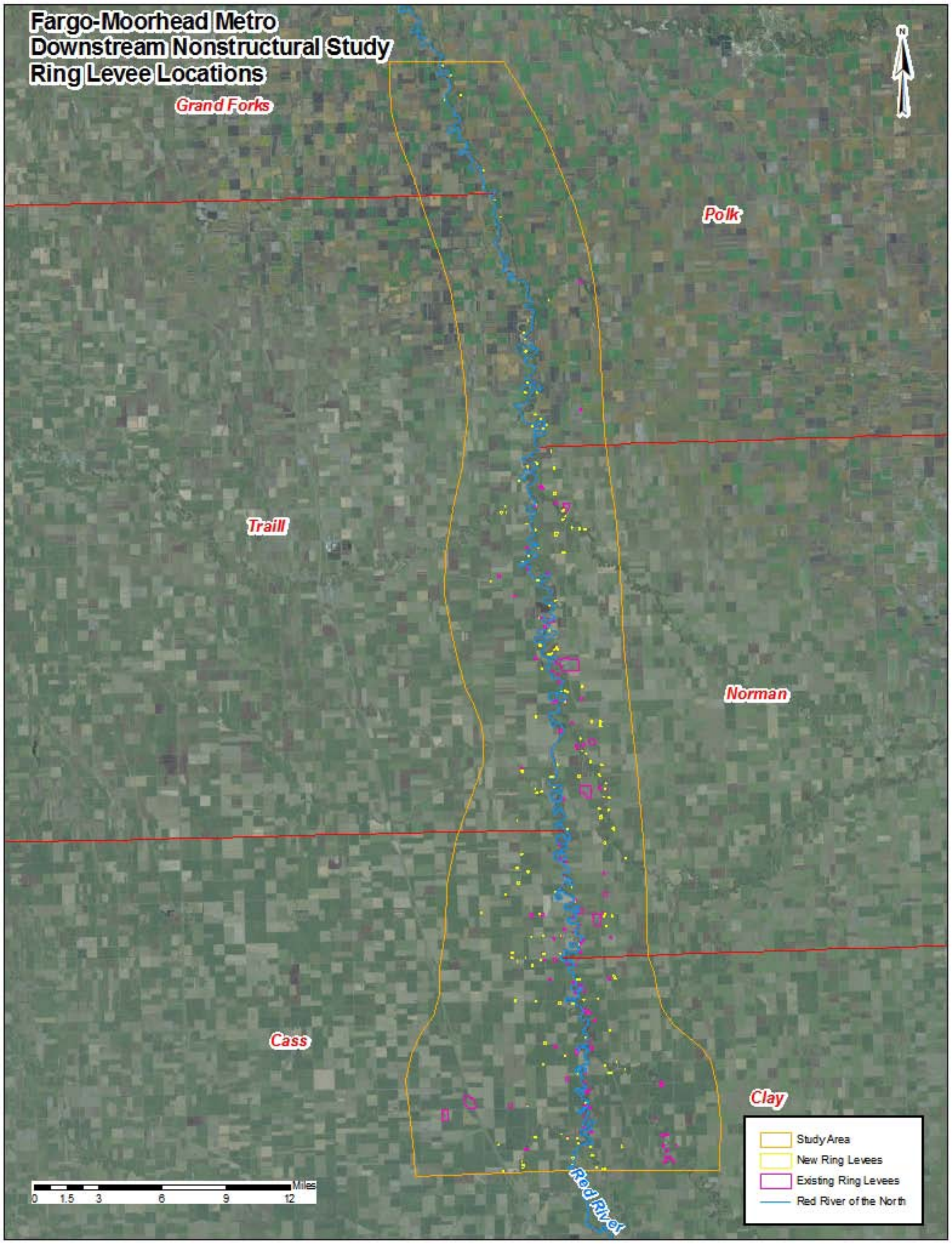
Structure GIS data was provided by MVP and supplemented through the various county GIS departments. The data was invaluable for determining the spatial locations of the structures in the economic analysis. The files provided structure location, plan view area and footprint. The economic data and structure GIS data were joined together through ArcMap and used as the base data.

Hydraulic data was also provided by MVP. The hydraulic model included cross sections for the Red River of the North. The elevations from the hydraulic model were used to determine the water surface elevation at each structure. The water surface elevations had already been assigned to the structures in the structure data provided from the economic analysis. The elevations were checked to the hydraulic model and found to be in good agreement.

The 100-year nonstructural flood risk reduction plan was completed for three economic subunits. The subunits include Cass, Trail, and Grand Forks Counties in North Dakota. In these three economic subunits, the residential structures were divided into six occupancy types; one story residential structures with basements, one story residential structures without basements, two story residential structures with basements, two story residential structures without basements and bi-level homes. The agricultural structures were divided into seven occupancy types; barns, grain bins, hay sheds, livestock sheds, machine sheds, shop sheds, and silos. The occupancy types for commercial and industrial structures were not divided for separate analysis.

The Fargo-Moorhead Metro downstream area is primarily rural. This results in a majority of the structures as being located separately or grouped together on farmsteads. In this situation, earthen berms, constructed as ring levees, may provide a lower cost method of providing protection to multiple structures. Existing ring levees can be raised or new ring levees can be built around the perimeter of the farmstead. A location map illustrating the location of new and existing ring levees within the North Dakota subunit are shown in Figure 11. As previously discussed, the use of ring levees is considered a nonstructural mitigation technique, when the berm or earthen ring levee is not certified according to FEMA regulations. The ring levees in this assessment were implemented based upon a 6-foot top width, a maximum of 2-foot of freeboard above the 100-year water surface elevation, and 2.5 horizontal to 1.0 vertical side slopes.

Figure 11
Ring Levee Locations Downstream from Fargo-Moorhead



Nonstructural flood risk reduction techniques were assigned to each structure investigated according to the criteria discussed in Report Section 2. These structures and techniques are summarized in Tables 16 to Table 18 for Grand Forks, Cass, and Trail Counties.

Table 16
Grand Forks County 100-Year Nonstructural Flood Risk Reduction Summary Table

Grand Forks County Flood Risk Reduction Summary Table			
Nonstructural Technique	**Structures**	**Total Cost**	**Cost / Structure**
Barn			
New Berm	1	$12,960	$12,960
OresWBsmt			
New Berm	1	$9,718	$9,718
100-Yr Plan Cost for Grand Forks County		$22,678	

Table 17
Cass County 100-Year Nonstructural Flood Risk Reduction Summary Table

Cass County Flood Risk Reduction Summary Table			
Nonstructural Technique	**Structures**	**Total Cost**	**Cost / Structure**
Barn			
Berm Raise	1	$13,175	$13,175
New Berm	3	$26,424	$8,808
Grain Bins			
New Berm	65	$339,187	$5,218
Berm Raise	56	$175,004	$3,125
Machine Sheds			
New Berm	85	$849,110	$9,990
Berm Raise	37	$326,092	$8,813
Main Floor Raise	1	$31,805	$31,805
Wet Flood Proof	3	$26,182	$8,727
OresWBsmt			
New Berm	17	$181,895	$10,700
Berm Raise	12	$145,999	$12,167
OresWOBsmt			
New Berm	1	$7,505	$7,505
Silo			
New Berm	2	$15,072	$7,536
Berm Raise	1	$13,175	$13,175
TresWBsmt			
Berm Raise	1	$10,268	$10,268
100-Yr Plan Cost for Cass County		$2,160,894	

Table 18
Trail County 100-Year Nonstructural Flood Risk Reduction Summary Table

Trail County Flood Risk Reduction Summary Table			
Nonstructural Technique	**Structures**	**Total Cost**	**Cost / Structure**
Barn			
New Berm	1	$16,565	$16,565
Main Floor Raise	2	$48,465	$24,232
Wet Flood Proof	1	$7,579	$7,579
Grain Bins			
New Berm	50	$197,174	$3,943
Berm Raise	17	$66,562	$3,915
Raise Main Floor	2	$23,892	$11,946
Machine Sheds			
New Berm	67	$571,014	$8,523
Berm Raise	16	$249,581	$15,599
Main Floor Raise	2	$85,906	$42,953
Wet Flood Proof	1	$6,890	$6,890
OresWBsmt			
New Berm	5	$48,140	$9,628
Berm Raise	2	$79,081	$39,540
OresWOBsmt			
New Berm	1	$25,216	$25,216
Shop Shed			
New Berm	1	$24,914	$24,914
Berm Raise	3	$21,459	$7,153
Silo			
New Berm	1	$6,899	$6,899
SplitWBsmt			
Berm Raise	1	$10,949	$10,949
TresWBsmt			
New Berm	4	$38,536	$9,634
Berm Raise	2	$49,283	$24,642
100-Yr Plan Cost for Trail County		$1,578,280	

4.2 North Dakota Nonstructural Project Benefits

Project benefits were calculated by St. Paul District using the HEC-FDA computer model. A modified with-project condition HEC-FDA input file was created for each economic subunit and the data was run in HEC-FDA to determine damages for the project condition. The difference between the without-project and with-project damages was then used as the project benefits. Table 19 illustrates these project benefits.

Table 19
North Dakota Downstream Nonstructural Plan Costs and Benefits

Economic Subunit	100-Yr Plan Total Cost	100-Yr Estimated Annual Cost	100-Yr Estimated Annual Benefits
Cass	$2,155,280	$119,189	$96,260
Trail	$1,578,280	$87,217	$56,960
Grand Forks	$22,678	$1,254	$786
Total 100-Yr Plan	$3,756,064	$207,660	$154,006

4.3 North Dakota Nonstructural Plan Summary

The nonstructural assessment for the North Dakota economic subunit which is located downstream from the Fargo-Moorhead Metro study area investigated numerous residential, commercial, and agricultural sector structures. A least-cost approach to assessing each structure impacted by a 100-year flood event was implemented. Where possible, particularly for farmsteads, where small groups of structures were located within the same proximity, earthen berms as ring levees were utilized. Otherwise, the additional nonstructural techniques described in Section 2 of this report were considered.

The North Dakota assessment indicated that there were significant benefits in implementing some nonstructural measures through the three-county economic subunits. When the structures are broken down to a structure by structure bases and structures are group within the ring levees, favorable projects emerged. Within Cass County there were 99 of 285 structures which appeared to result in a favorable benefit to cost ratio for implementing nonstructural measures. Within Trail County there were 47 of 179 structures which appeared to be feasible and in Grand Forks County the number was 1 out of 2 structures investigated. The data is summarized below in Table 20.

Table 20
Summary of Feasible Structures for North Dakota Downstream Nonstructural Plan

County	Feasible Structures	Net Benefit
Cass County	99	$23,554
Trail County	47	$6,512
Grand Forks County	1	$192

5.0 ` Nonstructural Plan for Minnesota Structures

For the Fargo Moorhead Metro Downstream Area, Minnesota side, the 100-year floodplain would inundate approximately 675 structures. These structures include residential and agricultural structures and are summarized by the economic subunit in Table 21. The water surface elevations for the 100-year project were determined from the existing conditions phase 3 hydraulic modeling completed by MVP. The structures were identified as being in the 100-year floodplain if the difference in the 100-year water surface elevation and the ground elevation was greater than zero. It is important to note here that the structures were not selected based on 100-yr floodplain delineations and the structure location.

Table 21
Structures Considered for Minnesota Downstream Nonstructural Plan

Economic Subunit	Residential Structures	Commercial Structures	Critical Facilities	Agricultural Structures
MN 100-Year Plan				
Clay County	69	3	2	144
Norman County	45	1	0	352
Polk County	8	0	0	54
Total	122	4	2	550

For the nonstructural flood risk reduction analysis Downstream of the Fargo-Moorhead Metro Area, a number of valuable datasets were obtained. Clay, Norman, and Polk Counties in Minnesota, and MVP provided the data for this study.

Detailed structure and economic data was provided by St. Paul district. The economic data was in the form of HEC-FDA output files and the files were the initial base data used to begin the analysis. For the economic analysis, the St. Paul District completed the assembly of ground elevations and foundation height for each structure Downstream of the Fargo-Moorhead Area. The ground elevations were extracted from Light Detection and Ranging (LiDAR) survey data and the foundation heights were determined by visually estimating the vertical distance from the ground and the foundation. The files provided occupancy type, property values, structure types, water surface elevations, ground surface elevations, and first floor elevations. Structure GIS data was provided by St. Paul District and supplemented through the various county GIS departments. The data was valuable to determine the spatial locations of the structures in the economic analysis. The files provided structure location, plan view area, and footprint. The economic data and structure GIS data were joined together through ArcMap and used as the base data.

The hydraulic model included cross sections for the Red River of the North. The elevations from the hydraulic model were used to determine the water surface elevation at each structure. The water surface elevations had already been assigned to the structures in the structure data provided from the economic analysis. The elevations were checked to the hydraulic model and found to be in good agreement.

5.1 Minnesota Nonstructural Plan Development

The 100-year nonstructural flood risk reduction plan was completed for three economic subunits. The subunits include Clay, Norman, and Polk Counties in Minnesota. In these three economic subunits, the residential structures were divided into six occupancy types; one story residential structures with basements, one story residential structures without basements, two story residential structures with basements, two story residential structures without basements and bi-level homes. The agricultural structures were divided into seven occupancy types; barns, grain bins, hay sheds, livestock sheds, machine sheds, shop sheds, and silos. The occupancy types for commercial and industrial structures were not divided for separate analysis. Nonstructural flood risk reduction techniques were assigned to the structure based on the criteria discussed in Report Section 2. These structures and techniques are summarized in Tables 22 to Table 24.

Table 22

Clay County 100-Year Nonstructural Flood Risk Reduction Summary Table

Clay County Flood Risk Reduction Summary Table			
Nonstructural Technique	**Structures**	**Total Cost**	**Cost / Structure**
Barn			
New Berm	1	$10,197	$10,197
Bilevel			
Elevate Entire Structure	1	$124,114	$124,114
Grain Bins			
New Berm	34	$55,502	$1,632
Berm Raise	17	$56,693	$3,335
Machine Sheds			
New Berm	41	$279,161	$6,809
Berm Raise	26	$238,633	$9,178
Main Floor Raise	2	$98,053	$49,027
Wet Flood Proof	21	$270,400	$12,876
OresWBsmt			
New Berm	12	$105,165	$8,764
Berm Raise	4	$20,963	$5,241
Main Floor Raise	13	$1,566,495	$120,500
OresWOBsmt			
Main Floor Raise	26	$1,789,258	$68,818
Silo			
Berm Raise	2	$6,577	$3,288
TresWBsmt			
New Berm	3	$24,635	$8,212
Berm Raise	2	$15,223	$7,612
Elevate Entire Sturcture	5	$653,297	$130,659
Fill Bsmt & Addition	1	$48,286	$48,286
Fill Bsmt & Pay	1	$42,678	$42,678
TresWOBsmt			
Main Floor Raise	1	$75,875	$75,875
100-Yr Plan Cost for Clay County		$5,405,328	

Table 23

Norman County 100-Year Nonstructural Flood Risk Reduction Summary Table

Norman County Flood Risk Reduction Summary Table			
Nonstructural Technique	**Structures**	**Total Cost**	**Cost / Structure**
Barn			
New Berm	4	$57,507	$14,377
Main Floor Raise	1	$33,277	$33,277
Wet Flood Proof	1	$10,400	$10,400
Grain Bins			
New Berm	114	$299,875	$2,630
Berm Raise	71	$213,469	$3,007
Hay Shed			
Buyout	1	$3,225	$3,225
Livestock Shed			
New Berm	2	$51,227	$25,613
Machine Sheds			
New Berm	115	$1,263,118	$10,984
Berm Raise	28	$348,717	$12,454
Buyout	1	$3,225	$3,225
Main Floor Raise	2	$60,071	$30,036
Wet Flood Proof	9	$85,800	$9,533
OresWBsmt			
New Berm	20	$261,336	$13,067
Berm Raise	6	$99,944	$16,657
OresWOBsmt			
New Berm	3	$66,009	$22,003
Shop Shed			
New Berm	1	$867	$867
Berm Raise	2	$12,169	$6,085
SplitWOBsmt			
New Berm	1	$2,836	$2,836
TresWBsmt			
New Berm	11	$184,569	$16,779
Berm Raise	4	$49,565	$12,391
100-Yr Plan Cost for Norman County		$3,107,206	

Table 24

Polk County 100-Year Nonstructural Flood Risk Reduction Summary Table

Polk County Flood Risk Reduction Summary Table			
Nonstructural Technique	**Structures**	**Total Cost**	**Cost / Structure**
Barn			
New Berm	3	$63,000	$21,000
Main Floor Raise	1	$13,539	$13,539
Grain Bins			
New Berm	20	$110,025	$5,501
Machine Sheds			
New Berm	30	$452,800	$15,093
OresWBsmt			
New Berm	8	$119,269	$14,909
100-Yr Plan Cost for Polk County		$758,632	

5.2 Minnesota Nonstructural Project Benefits

Project benefits were calculated by MVP using the HEC-FDA computer model. A modified with-project condition HEC-FDA input file was created for each economic subunit and the data was run in HEC-FDA to determine damages of the project condition. The difference between the pre-project and with-project damages was then used as the project benefits. Table 25 displays these project benefits.

Table 25
Minnesota Counties Nonstructural Plan Summary

Economic Subunit	100-Yr Plan Total Cost	100-Yr Estimated Annual Cost	100-Yr Estimated Annual Benefits
Clay	$5,503,243	$304,335	$69,039
Norman	$3,029,197	$167,518	$135,353
Polk	$585,556	$32,382	$16,302
Total 100-Yr Plan	$9,117,996	$504,235	$220,694

5.3 Minnesota Nonstructural Plan Summary

The nonstructural assessment for the Minnesota economic subunit which is located downstream from the Fargo-Moorhead Metro study area investigated numerous residential, commercial, and agricultural sector structures. A least-cost approach to assessing each structure impacted by a 100-year flood event was implemented. Where possible, particularly for farmsteads, where small groups of structures were located within the same proximity, earthen berms as ring levees were utilized. Otherwise, the additional nonstructural techniques described in Section 2 of this report were considered.

The Minnesota assessment indicated that there were significant benefits in implementing some nonstructural measures through the three-county economic subunit. When the structures are broken down to a structure by structure bases and structures are group within the earthen berms favorable projects emerged. Within Clay County there were 30 of 185 structures which appeared to result in a favorable benefit to cost ratio for implementing nonstructural measures. Within Norman County there were 151 of 399 structures which appeared to be feasible and in Polk County the number was 3 out of 64 structures investigated. The data is summarized below in Table 26.

Table 26
Summary of Feasible Structures for Minnesota Downstream Nonstructural Plan

County	Feasible Structures	Net Benefit
Clay County	30	$17,629
Norman County	151	$45,303
Polk County	3	$1,808

6.0 Summary of Nonstructural Assessment

The approach to this investigation was to determine the potential for implementing nonstructural measures downstream from the Fargo-Moorhead Metro area, outside of the influence of the proposed diversion channel project. The study area was widespread taking in parts of 6 counties, 3 in Minnesota and 3 in North Dakota. Over 3,800 structures were investigated, first, for being impacted by a flood event equal to or greater than a 100-year event, and secondly, for a least-cost approach to implementing nonstructural measures.

While the study area consisted of many residential and commercial structure types, there were also numerous barns, machine sheds, grain bins, and silos. These structures are more common to rural areas, where agriculture is the leading industry. For these structure types, nonstructural techniques of elevating the structure, elevating a false interior floor, wet flood proofing, or dry flood proofing was considered.

In many instances where farmsteads were identified, the structure types consisted of residential, barn, sheds, bins, and silos. Where practical, groups of structures were protected by ringing the perimeter of such groups of structures with earthen berms. Since the berms are meant to be designed using sound engineering practices, they could meet or exceed FEMA levee accreditation standards. However, constructing certified levees is not the primary goal or objective of this nonstructural assessment. Rather, this assessment is concerned with recommending measures which use sound engineering design standards to protect to a sufficient height during a specified flood event. With that in mind, the application of nonstructural berms has been identified as a nonstructural mitigation measure.

Of the 1,117 structures assessed in detail, 395 or 35% of the structures were found to be qualified for nonstructural mitigation. Many of the 395 examples consist of ring levees where more than one structure is being protected from flooding. Numerous worksheets were developed for this investigation and contain the individual structure and groupings of structures. Since the floodplain is characteristically flat, there were no geographical subareas within which to subdivide into smaller economic units. This is why political boundaries, divided along county lines, were used to subdivide the total study area.

7.0 Nonstructural Plan Recommendations

This supplemental nonstructural assessment in support of a complex flood risk reduction study being conducted by the US Army Corps of Engineers, St. Paul District, the states of North Dakota and Minnesota, and the metropolitan area of Fargo and Moorhead, resulted in the identification of feasible nonstructural measures. While the task was to investigate the impacts of flooding from a 100-year flood event downstream from the protective influence of a proposed diversion channel project, the vastness of the study area, all within portions of six counties, made the process difficult, and reliance upon automation of the investigation became mandatory. The automated assessment process, which is illustrated by the flowcharts shown in Section 3 of this report, was used to expedite the investigation and to determine economic feasibility.

It was found that nonstructural mitigation in the form of elevation, dry flood proofing, wet flood proofing, and through berms, could provide economically feasible flood risk reduction to more than a 35% of the structures investigated and should be considered for implementation in support of the ongoing efforts to reduce flood damages along the Red River of the North.