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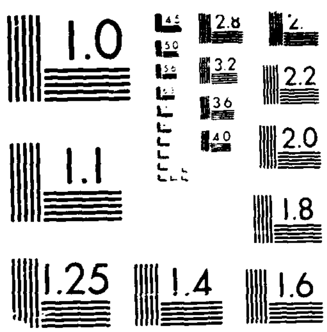

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THE APPLICATION OF OPTIMUM VALUE ENGINEERING DESIGN AND CONSTRUCTION TECHNIQUES TO THE U. S. NAVY'S HOUSING CONSTRUCTION CONTRACT REQUEST FOR PROPOSAL

1988

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THE APPLICATION OF OPTIMUM VALUE ENGINEERING DESIGN AND CONSTRUCTION TECHNIQUES TO THE U.S. NAVY'S HOUSING CONSTRUCTION CONTRACT REQUEST FOR PROPOSAL

A Thesis in

Civil Engineering

by

Michael A. Giorgione

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of the Requirements
for the Degree of

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ABSTRACT

This research study examines the nature and applicability of Optimum Value Engineering (OVE) design and construction techniques in the U.S. Navy's housing construction contract Request For Proposal (RFP). OVE techniques and findings are discussed, the RFP process is explained and the interface between the two is examined and defined. A Navy family housing project and other reference projects are used for the investigation of current and proposed OVE techniques. As a result, modifications to the current RFP are recommended, based on the case study findings, cost analysis of several key items and the author's personal experience.

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GLOSSARY OF TERMS

AFFORDABLE HOUSING STUDIES - Residential construction studies monitored and published by NAHB on the OVE design and construction of over 30 residential developments in different cities throughout the United States.

AIR RELIEF VALVE - An automatic valve located at high points on a water line and used to automatically relieve trapped air to the atmosphere.

ANSI - American National Standards Institute; publishers of construction material and performance specifications.

ARCHITECT-ENGINEER - A/E; a professional design firm.

BLOW-OFF VALVE - A valve located at low points or at terminal ends on a water line and used to flush the line of sediment and contaminated water.

ASHRAE - American Society of Heating, Refrigeration and Air Conditioning Engineering Guide; publishers of HVAC material and performance specifications.

BRIDGING - The diagonal members installed between floor joists in a first floor floor system that is located over a basement or crawlspace.

CABO - Council of American Building Officials Code; a consolidated residential building code based on criteria and guidelines from several national building codes.

CATV - Cable antenna television system.

CELLULOSE ACETATE BUTYRATE - CAB; a plastic material used for natural gas lines in residential units.

CHLORINATED POLYVINYL CHLORIDE - CPVC; a plastic material used in plumbing systems.

CLEANOUT - A combination plug and pipe system used to access and remove sediment from sanitary sewer lines.

COMMERCE BUSINESS DAILY - CBD; a periodical published weekly and containing such information as solicited and awarded Government construction contracts.

CURVILINEAR - A long, curved line; usually used in reference to streets or water and sewer lines.

DWV - Drain-waste-vent; referring to components of a residential plumbing system.

ENGINEERING FIELD DIVISION - One of six subordinate commands to NAVFACENGCOM responsible for engineering duties and responsibilites within their specific geographical area of the world.

EPOXY REINFORCED FIBERGLASS - EFG; a plastic material used for natural gas lines in residential units.

FEDERAL ACQUISITION REGULATIONS - FAR; the current federal procurement and acquisition regulations governing Government contracts.

HOUSING AND URBAN DEVELOPMENT; DEPT. OF; One of the twelve secretarial Cabinet posts in the United States executive branch.

HVAC - Heating, ventilation and air conditioning; mechanical systems found in a residential unit.

HYDRAULIC EFFICIENCY - The measure of a sanitary sewer system's performance in terms of slope, velocity, roughness coefficient of the pipe and quantity of flow.

LANTDIV - Atlantic Division, Naval Facilities Engineering Command; one of the six EFDs under NAVFAC, responsible for the Atlantic region of the U.S. and for Southern Europe, Northern Africa and the Mediterranean.

MONOLITHIC - Pertaining to concrete slabs, the placement of the concrete slab and footings in a single pour.

MULTIFAMILY UNITS - Housing units connected in a single building.

NAHB - National Association of Home Builders; a national research, publishing and information agency dedicated to the home bulding process.

NAVAL FACILITIES ENGINEERING COMMAND - NAVFACENGCOM or NAVFAC; the component of the Department of the Navy responsible for facilities management, maintenance and construction and for worldwide construction mobility and disaster preparedness.

NEC - National Electric Code; a national code governing electrical construction and maintenance.

OFFICER IN CHARGE OF CONSTRUCTION - OICC; any one of several subordinate commands under a EFD, responsible for construction and maintenace contracts at a specific installation or area.

OPTIMUM VALUE ENGINEERING - OVE; a procedure for comparing and choosing one of several alternative methods and materials in construction to achieve the least costly combination that will result in an acceptable product.

PLAN OF ACTION & MILESTONE SCHEDULE; POA&M; a milestone schedule established by an EFD that outlines the tentative action dates for the stages of a Navy family housing project.

POLYETHYLENE - PE; a plastic substance used in manufacturing water and sewer lines and accessories.

POLYVINYL CHLORIDE - PVC; a plastic substance used in manufacturing water and sewer lines and accessories.

PRE-PROPOSAL CONFERENCE - A conference conducted by an EFD, OICC or ROICC to aid proposers in responding to housing contract Request For Proposals (RFP).

PUBLIC WORKS CENTER - PWC; one of seven large public works activites located at various installations throughout the world.

PUBLIC WORKS DEPARTMENT - PWD; a smaller version of a PWC, located at medium and small sized installations throughout the world.

RESIDENT OFFICER IN CHARGE OF CONSTRUCTION - ROICC; any one of several subordinate activites to an OICC, responsible for the administration of construction contracts on a specific installation or geographical area.

REQUEST FOR PROPOSAL - RFP; one of the standard contract documents used by NAVFAC to administer housing construction contracts; contains applicable design and construction standards and codes, FAR Clauses, quality control and safety requirements and specific information relevant to the site location and environment of the project.

SMART HOUSE - An electrical design for a house that incorporates a single cable wiring system with a central control panel.

SOIL BEARING CAPACITY - Measured in pounds per square foot, the pressure that a soil can support before failure, determined in the field by pressure plate testing, or assumed for a certain type of soil based on empirical tables.

STICK-BUILT - Referring to the construction of a house, the erection on site with individual wood or metal framing members.

VALUE ENGINEERING - A process used in construction to determine the most economical approach to follow in a specific construction activity.

WELDED WIRE FABRIC - WWF; a steel mesh installed in concrete slabs to aid in the control of shrinkage cracking.

ZERO LOT LINE - The placement of one of the sides of a unit directly on a side lot line to provide one larger and more useable side yard rather than two smaller side yards.

ACKNOWLEDGEMENTS

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CHAPTER ONE

INTRODUCTION

Background

U.S. Navy Housing

The Armed Forces of the United States maintain military installations throughout the United States and in over fifty foreign countries and U.S. territories. At most of these installations, military housing is maintained and in many cases, current repair and construction projects are in progress or new projects are planned for the future. This situation is common throughout the Armed Forces, including the U.S. Navy.

Facilities maintenance and construction for U.S. Navy installations is part of the mission of the Naval Facilities Engineering Command, headquartered in Alexandria, Virginia. Over the past ten years, the Naval Facilities Engineering Command, or NAVFAC, has used a design-construct or turnkey contract approach to satisfy their military personnel housing needs. NAVFAC awards and administers the design-construct contracts through competitive bidding and technical evaluation and review of the submitted contractor proposals.

For a Navy housing contract, the successful proposer is required to satisfy design criteria and special conditions contained in the Request For Proposal (RFP). The RFP contains the applicable design and construction standards and codes, Federal Acquisition Regulation (FAR) Clauses, quality control and safety requirements and specific information relevant to the site location and environment of the project, whether in the United States or in a foreign country.

The RFP currently used by NAVFAC is a comprehensive outline of design and construction standards and performance specifications. Depending on the location of the housing contract, cognizant field activities are responsible for tailoring the RFP to accomodate their specific field conditions and requirements. These field activities involve EFDs (Engineering Field Divisions), OICCs (Officers in Charge of Construction), ROICCs (Resident Officers in Charge of Construction), PWCs (Public Works Centers) and PWDs (Public Works Departments). The organizational structure of NAVFAC is provided in Appendix A.

An example of specific RFP modifications would be the ones which applied to the housing construction contract at the U.S. Naval Facility, Subic Bay, Republic of the Philippines that included the following conditions: special stormwater management requirements due to the excessive annual rainfall (approximately 200 inches per year), guidance on special local labor practices and conditions based on the current Military

Bases Agreement and the requirement to import the majority of the construction materials from the United States. These types of RFP modifications would not be included, however, in any RFP for military housing at a base in the United States, such as Adak, Alaska, or Yuma, Arizona. Housing contracts at these sites would include their own special conditions.

Although each field activity is required to modify the RFP, and is better qualified to do so than the major parent command, NAVFAC, there may be many opportunities to standardize basic design and construction principles in order to achieve reduced costs of housing almost anywhere in the world. One opportunity could be through the use of Optimum Value Engineering design and construction techniques.

Optimum Value Engineering

Optimum Value Engineering (OVE) is a procedure for comparing and then choosing one of several alternative methods and materials in construction to achieve the least costly combination that will result in an acceptable product. In residential construction, this involves the selection of certain house designs, materials and products that represent the least costly and still acceptable combination in terms of safety and quality (1).

OVE was initially developed by the National Association of Home Builders (NAHB) Research Foundation, Inc. in the early 1980's through a contract from the U.S. Department of Housing and Urban Development. The purpose of the contract was to reduce home building costs through engineering considerations of common and available building materials and labor skills . The history, research findings and OVE guidelines developed by NAHB are contained in their published reference, Reducing Home Building Costs With OVE Design and Construction (1).

Comparison With Value Engineering

Similar in nomenclature to Optimum Value Engineering is Value Engineering. Value Engineering was developed during World War II as shortages of critical resources required changes in methods, materials and traditional designs in order to achieve improved performance at a lower cost. Afterwards, the General Electric Company created a formal value analysis program for commercial industry that was quickly adopted and modified by other industry leaders and U.S. Government agencies (2).

In 1962, Value Engineering was included as a requirement in the Armed Services Procurement Regulations (ASPR) (presently the Federal Acquisition Regulations (FAR)). This addition to the ASPR affected the operations of two of the largest construction agencies in the nation, the U.S. Navy Bureau of Yards and Docks (presently NAVFAC) and the U.S. Army Corps of Engineers. Following their lead, other government agencies such as the National Aeronautics and Space Administration (NASA), Department of Transportation, General Services Administration (GSA) and the Bureau of Reclamation implemented Value Engineering guidelines and requirements over the next fifteen years (2).

Value Engineering studies are normally performed before detail design is completed in order to determine the most economical approach to follow during the project. The studies usually result in modified design details, materials selection and construction methods that still satisfy all quality and specification requirements, yet at a lower cost to the Owner and Contractor. In 1974, the Army Corps of Engineers estimated a cumulative annual savings of approximately $234 million due to Value Engineering (2).

Value Engineering is normally most effective when each party to a contract is involved in design review and analysis in order to identify alternative methods or designs that will result in a savings. This review and analysis is frequently completed prior to the start of construction in order to minimize job disruption and achieve the greatest savings.

In current NAVFAC construction contracts greater than $100,000, a Value Engineering Change Proposal (VECP) Clause is included to recognize potential savings that may be identified during the actual stages of construction. Although this Clause may be effective in several large cases, it is often too difficult to administer and, therefore, disregarded, especially if the construction phase is fairly well along.

OVE does not pertain to the construction stage of a project, but is instead best suited to the preconstruction or design stages of the project.

The relevance of OVE in the preconstruction stages of a housing contract can be explained by referring to Figure 1. Figure 1 indicates that the highest level of influence at the lowest cost is available during the Engineering/Design phase, whereas the lowest level of influence at the highest cost occurs during the Procurement/Construction phase of a construction project. OVE, therefore, concentrates on the Engineering/Design phase of a residential construction project in order to reduce development and construction costs.

OVE Studies

In conjunction with the initial OVE study, there have been many Affordable Housing Studies completed by the NAHB Research Foundation that parallel and

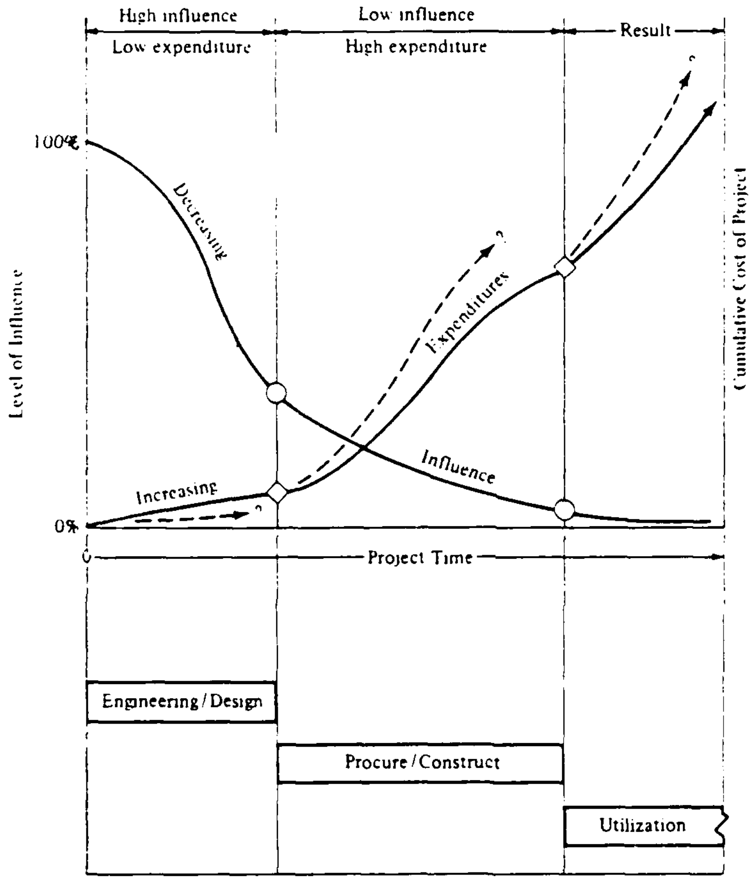


Figure 1. Level of Influence on Project Costs. (From Professional Construction Management, Barrie and Paulson.)

contribute to the OVE research. These Affordable Housing Studies have identified ways to reduce costs in land development, design and various phases of construction. Their results have yielded descriptions of proven techniques that have been successful in various residential developments throughout the country (1).

Some of these proven techniques concentrate on the land development and infrastructure construction phase. Site design, street design, storm drainage and utilities have been specificallly studied in order to identify and develop methods which have a high potential for cost savings. NAHB completed over twenty case studies throughout the United States in areas such as Fairbanks, Alaska, Phoenix, Arizona, Knox County, Tennessee, Sioux Falls, South Dakota, and Greensboro, North Carolina.

The original OVE study completed by NAHB concluded with a variety of design and construction recommendations which would reduce home building costs and result in more affordable homes. In one actual prototype house, a total direct cost savings of more than 12% was achieved, with 69% of the savings found in material and 31% of the savings found in labor. Overall, the study examined modular planning and design, foundation construction, floor construction, exterior wall construction, roof construction and interior partitions and finishes. Although the study focused largely on conventional wood frame construction of single family detached houses, most of the techniques also apply to other housing types such as duplex, fourplex, garden court and townhouses. The techniques also apply to on site and shop or prefabricated building methods (1).

These are exceptionally important areas to consider since they describe virtually all of the types of housing currently built under U.S. Navy construction contracts. Most common are multifamily units at domestic and foreign bases because such construction achieves the greatest popoulation density for limited available land and continually reduced development and construction funds. In addition, housing contracts at foreign bases now mandate that prefabricated structural components must be used in design and construction. U.S. Navy housing should, therefore, consider Optimum Value Engineering design and construction principles in order to benefit from the recommendations of the Affordable Housing Studies.

Purpose

The purpose of this research study is to evaluate Optimum Value Engineering design and construction techniques and determine if they can be applied to modify and improve the current U.S. Navy Request For Proposal for Navy housing.

The combined results of the OVE and Affordable Housing Studies have identified eight major subdivisions of the residential development and building process that can be examined for potential cost savings (1,3,4):

1. Site Design and Development
2. Site Utilities
3. Foundations
4. Floor Systems
5. Wall Systems
6. Roof Systems
7. Support Systems
8. Building Materials

Each of these major subdivisions will be examined in this report with respect to the U.S. Navy's current Request For Proposal and to a study of one of the current Navy housing construction contracts. Site Design and Development and Site Utilities will be examined in greater detail than the other items since these areas provide the greatest opportunity for design and construction savings.

Recommended modifications, if implemented, could enhance the quality and affordability of housing built for the Navy. Application of these recommendations in a modified RFP could then be evaluated in actual construction contracts and further modifications could also be studied and implemented.

Problem Definition

Problem Statement

Due to the expanding mission of the U.S. Navy towards the 600 ship Navy, and the growth of its personnel ranks, new housing on many bases is being programmed, funded and constructed. The annual level of new housing construction has averaged approximately $100 million per year since 1981 and has yielded a current inventory of 70,350 housing units representing all U.S. Navy facilities worldwide.

The programming, funding and construction dollars, however, are continually scrutinized and reviewed by Congress, and as a result, project budgets and scopes are commonly reduced or altogether eliminated. One critical housing project to be built at the U.S. Naval Facility, Subic Bay, Republic of the Philippines has been postponed the past two years due to funding limitations and political uncertainty concerning the U.S. Bases in the Philippines. The current FY 1988 Military Construction Budget before Congress includes funding for a requested 1000 units, yet may be reduced due to restrained spending policies.

In order to reduce the amount of required funding for a new housing construction contract, modifications to the current U.S. Navy contracting system can possibly be made to achieve more affordable housing. One possible modification is the revision of the housing construction contract Request For Proposal (RFP) to include Optimum Value Engineering (OVE) design and construction techniques. This could provide acceptable design and construction standards at a reduced cost. It is, therefore, worthwhile to conduct a research study which evaluates the application of OVE techniques to determine if more affordable housing can be achieved. If possible, it could be determined that quality design and construction standards can still be achieved, yet at a more affordable cost to the U.S. Navy and taxpayers. The savings, if appreciable, could then allow more projects or more units per project to be built, or allow other U.S. Navy construction projects to be funded.

Figure 2 illustrates the two areas to be examined and where their interface exists. As previously noted, the Request For Proposal (RFP) is the standard contracting document the U.S. Navy uses for their housing construction projects. Dealing directly with residential construction is the concept of Optimum Value Engineering (OVE) as identified and developed by the NAHB Research Foundation. The interface in Figure 2

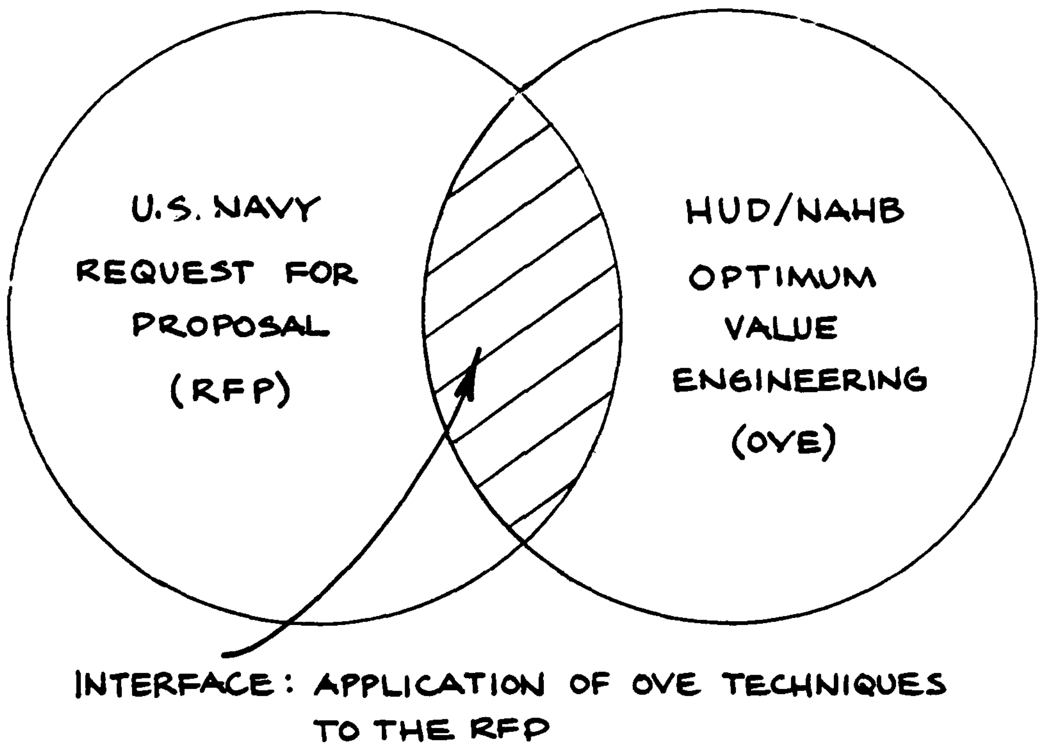


Figure 2. The Relationship Between OVE and the RFP.

defines where OVE design and construction techniques can be applied to the RFP to possibly improve constructed housing.

Objectives

The objectives of this research study are as follows:

1. Identify the recommended design and construction principles and techniques used in residential development and construction that can help to reduce home building costs.

2. Explain how these techniques can be applied to the U.S. Navy's housing construction contract Request For Proposal.

3. Determine through personal experience and a case study of a current U.S. Navy housing construction contract if OVE design and construction techniques can be implemented to achieve reduced home building costs.

4. Present results and recommendations of research study to the Naval Facilities Engineering Command.

Methods

In order to discuss and then attempt to apply Optimum Value Engineering design and construction techniques to the U.S. Navy's housing Request For Proposal, the author used three research techniques.

The first technique involved an extensive literarture search and review of publications dealing with OVE and other innovative and cost effective design techniques. The majority of the literature reviewed was published by the U.S. Department of Housing and Urban Development (HUD) and the National Association of Home Builders (NAHB) Research Foundation, Inc. in the 1980's. The material published by these two agencies was then supplemented by general house design and construction references that discussed cost effective design modifications and affordable housing. It is noted that most of the concepts discussed and applied in this thesis represent relatively modern developments (1980's).

In conjunction with the literature search and review, the author visited the U.S. Department of Housing and Urban Development and the NAHB Research Foundation on several occasions to conduct personal interviews concerning the applicability of Optimum Value Engineering to U.S. Navy housing. Since both agencies are frequently contracted by the Armed Services, including the U.S. Navy, to complete military housing studies, their understanding of the intent of this thesis was excellent and their input and recommendations were valuable to the author.

It should be noted that the author's personal experience as a U.S. Navy contracting officer, responsible for the administration of a $24.5 million 300 unit turnkey housing construction contract at the U.S. Naval Facility, Subic Bay, Republic of the Philippines, provided him with the necessary background to analyze the applicability of OVE design and construction techniques to U.S. Navy housing.

Although HUD and NAHB have tested their OVE ideas in a number of residential markets across the United States with their Case Demonstration and Affordable Housing Studies, and documented these studies with cost savings reports and lessons learned (5), a case study involving a current U.S. Navy housing contract was considered appropriate as the third and final research technique. The project selected was Contract N62740-85-C-0054, Woodbridge Crossing, A 300 Unit Apartment Project, Newport News, Virginia.

Unlike the NAHB Case Demonstration Studies for affordable housing, this project was not administered under the guidelines of OVE design and construction since these techniques were not a part of the initial Request For Proposal. Instead, the project was analyzed for possible design and construction changes that may have resulted in a cost savings to the prime contractor and the U.S. Navy if the OVE guidelines had been included in the RFP.

The project plans were first reviewed and places where OVE design and construction techniques could have been applied were identified. A site visit then allowed the author to witness the actual construction of the housing units, interview the prime contractor and discuss the feasibility of using the recommended OVE modifications.

The observations and findings from the case study allowed the author to determine if the use of OVE design and construction techniques could have resulted in a cost savings for the contractor and for the U.S. Navy, in terms of construction program funds and future maintenance year funds.

Thesis Organization

Chapter Two, Navy Housing Request For Proposal, describes the typical stages in the life of a housing project and how a selection is made based on proposer design submissions. The various components of the RFP are discussed, with emphasis on the RFP section that could be modified to include OVE design and construction techniques. In addition, the unique features of turnkey construction are discussed since it is the contractural arrangement used by the U.S. Navy for military family housing.

Chapter Three, OVE Design and Construction Techniques, addresses the various cost saving ideas and methods that can be used in residential construction. The eight subdivisions of OVE and innovative design are presented with emphasis on the areas of Site Design and Development and Site Utilities and Storm Drainage.

The Navy Housing Case Study is described and presented in Chapter Four. In particular, results of interviews with Navy contracting officials and Contractor representaives concerning the use of OVE techniques are included.

Chapter Five, Application of OVE Techniques to the RFP, addresses how the current Housing RFP can be modified to include proven OVE and other innovative ideas and techniques. Recommendations to modify current RFP criteria and guidelines are made on the basis of RFP design standards, the author's personal experience and results from the housing case study.

Chapter Six, Results and Conclusions, summarizes the author's findings and recommendations concerning the application of OVE design and construction techniques to the U.S. Navy's Housing Request For Proposal.

CHAPTER TWO

NAVY HOUSING REQUEST FOR PROPOSAL

In order to examine the Navy Housing Request For Proposal (RFP) and attempt to apply Optimum Value Engineering techniques, it is first necessary to define the RFP procedure and explain how it is used in Navy housing construction contracts. This chapter will provide that explanation.

Housing Contract Milestones

The Naval Facilities Engineering Command (NAVFAC) has used a turnkey approach for their new housing construction projects for the past twelve years. This approach involves the following typical stages in the life of a housing project (see Figure 3):

1. A housing need is identified by a cognizant Naval facility, whether at a foreign or domestic base. Normally the need for additional housing is forecast years in advance and included in the facility's master plan.

2. Funding is requested by NAVFAC from Congress to support the project and all related costs. This funding request is part of the annual budget submittal from NAVFAC to Congressional Subcommittees that monitor and approve military construction programming and funding.

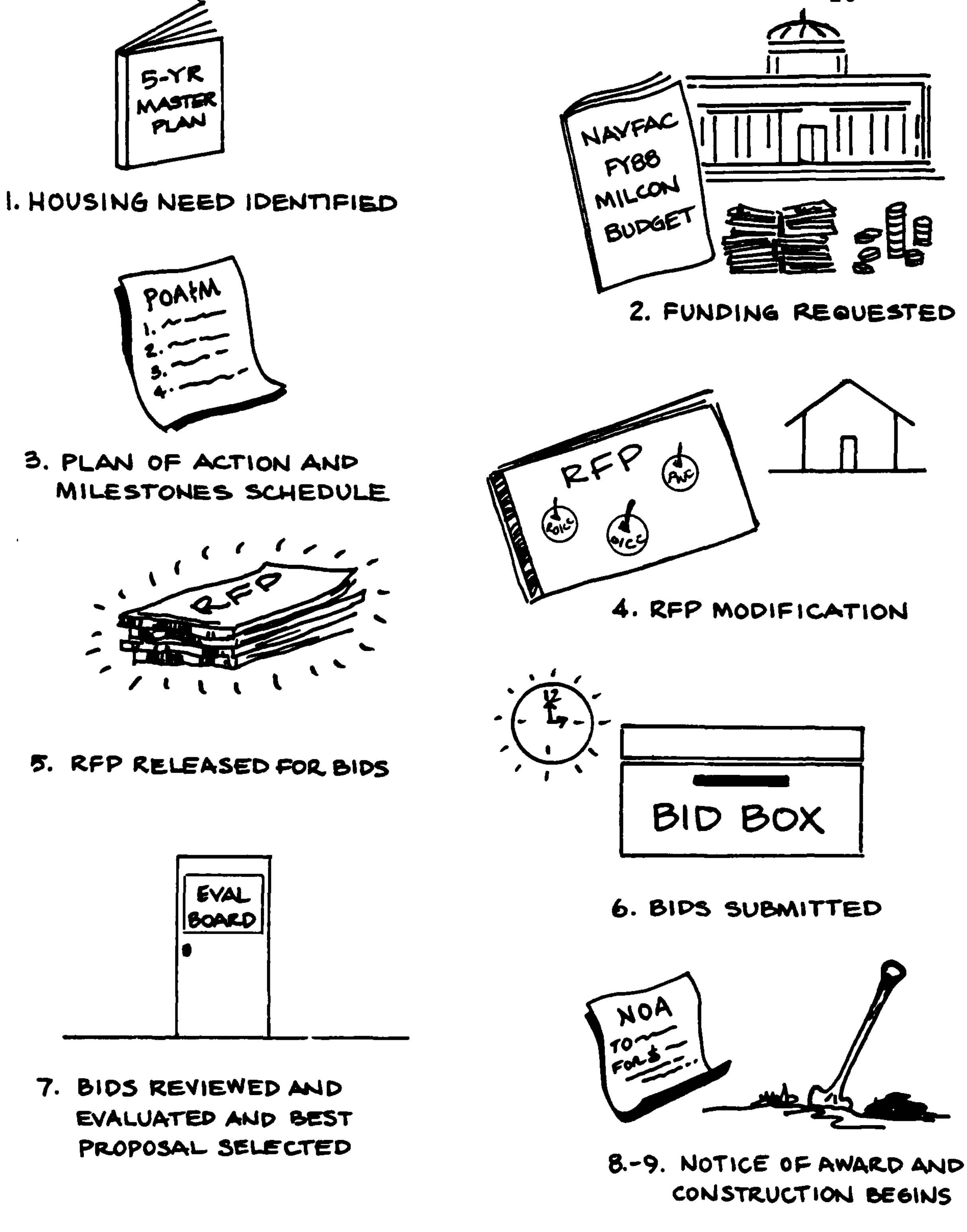


Figure 3. Sequence of Events in the Life of a Navy Housing Project.

3. If funding is approved, a Plan Of Action and Milestone (POA&M) Schedule is established by the cognizant Engineering Field Division (EFD) and is distributed to all involved parties at the user facility. The involved parties include the cognizant Officer in Charge of Construction (OICC), the Resident Officer in Charge of Construction (ROICC) and the Public Works Center or Department (PWC or PWD). (See Appendix A.)

4. Within the early stages of the POA&M Schedule, a review and modification of the standard Request For Proposal is completed. The Request For Proposal (RFP) is one of the standard contract documents that NAVFAC uses to administer housing construction contracts. It contains general contract information and in particular, it outlines the design and construction criteria that prospective contractors and Architect-Engineers must follow in their bids. The standard RFP consists of four major sections (6):

SECTION 1 - GENERAL: General procedures and requirements concerning proposals and the construction contract.

SECTION 2 - DESIGN AND CONSTRUCTION: Design and Construction Criteria, Site Design and Construction, Dwelling Unit Design and Construction, Construction and Materials, Structural Standards and Design, Mechanical, Electrical and Plumbing, Energy Requirements.

SECTION 3 - CONTRACTOR QUALITY CONTROL: Requirements, Controls, Plan, Tests and Inspections, Certifications and Forms.

SECTION 4 - STANDARD TECHNICAL EVALUATION MANUAL FOR TURNKEY NAVY FAMILY HOUSING PROJECTS: Purpose, Evaluation Areas, Technical Evaluation Factors.

Appendix B of this report provides the Table of Contents of the typical RFP.

Sections 3 and 4 are standard and do not normally require modification as they are consistent at almost every site. Sections 1 and 2, however, do require close review and modification in order to represent the conditions truly found at the construction site.

Section 1, General, addresses general requirements descriptive of the site, local conditions, labor situation and environmental conditions.

Section 2, Design and Construction, is the major section of the RFP, essentially instructing all proposers as to what should be included in the project. As a part of the subsequent signed contract between the U.S. Navy and successful proposer, it also serves as a legal description of what is required by the contract. Optimum Value Engineering techniques could be applied to Section 2, resulting in modified guidelines from which each proposer could choose.

Review and modification of Sections 1 and 2 is best completed by the user facility, the PWC or PWD, and the cognizant OICC and ROICC. For OVE techniques to be implemented, however, changes must be made to the standard RFP so that all housing contracts in any location can take advantage of the innovative design and construction guidelines. It is the author's opinion that the standard RFP must already contain OVE modifications, prior to any modifications made at the actual project site, if there is to be any chance that they will be adopted.

5. After all reviews are completed, the final RFP is printed. Following notification of the project in the Commerce Business Daily (CBD) and other required documents or publications, the RFP is released for proposer review. Frequently, a Pre-Proposal Conference is held at the EFD or actual project site to answer proposer questions concerning the RFP and its requirements and guidelines.

6. After a predetermined time from the release date of the RFP, usually sixty days unless there are amendments to the RFP extending the proposal due date, all proposals are due at the EFD. These proposals include a preliminary design of the site and dwelling units, completed forms and a total bid price for the entire project.

7. A selected design review team, normally composed of engineers and architects from the EFD, form a technical evaluation board and are responsible for reviewing and grading each unidentified proposal. (Proposals are assigned a proposal number by the

Contracts Department at the EFD. The identity of the actual contractor is not publicized during the technical evaluation.) During the evaluation, quality points are awarded for each design section which is identified in the RFP. One thousand (1000) rating points are assessed to the following major categories:

Site Design	20%
Site Engineering	10%
Dwelling Unit Design	50%
Dwelling Unit Engineering and Specifications	20%
Technical Evaluation Total	100%

8. Since NAVFAC uses a turnkey evaluation approach to the housing contract, the successful proposer is selected on the basis of the lowest dollar to quality point ratio. For example, let it be assumed that four proposers submit the following proposals with the total bid price and evaluation points awarded by the technical evaluation team as indicated below:

	Price ($M)	Points	Ratio ($/PTS)
Proposer No. 1	28	970	28,866
Proposer No. 2	25	920	27,174
Proposer No. 3	25	910	27,472
Proposer No. 4	26	960	27,083

Based on the dollar to quality point ratios, the successful proposer would be Proposer No. 4. It is noted that neither the lowest proposer in terms of price (Proposer No. 2 or No. 3) nor the proposer with the highest quality points (Proposer No. 1) is necessarily selected.

9. Following selection of the successful proposer, the Notice of Award and the final signing of all contract documents, the administration of the contract by the U.S. Navy and final design and construction by the contractor begins.

Uniqueness of Turnkey Construction

The turnkey contract approach used by NAVFAC for housing contracts is unique since it selects one prime contractor who is responsible for both design and construction. Since the contractor and not a Government contracted Architect-Engineer (as on most other construction projects) is responsible for design, the final design is not the direct responsibility of the Government in terms of correctness, completeness, accuracy and liability. While this may be viewed as a very convenient factor during the contract administration stage, it presents several critical limitations.

One limitation is that the Navy cannot direct specific design guidelines and features beyond the scope of the RFP. In a contracted A-E situation, the Navy could make design changes during the various design review stages (35%, 60%, 90% and Final) and be assured of what will be built by the contractor who is awarded the contract. With a turnkey contract, however, what the successful proposer offers is essentially what the Navy gets, unless additive or deductive change orders are issued. It should now be evident that the completeness and accuracy of the design and construction guidelines in Section 2 of the RFP is very critical to the total process. If the Navy does not mandate certain design features, then they will probably not be included in the proposer's design.

Unlike the Case Demonstration Studies completed by NAHB, the Navy is, therefore, not able to directly select an independent contractor and mandate how a housing development will be built. Therefore, the Navy also cannot directly mandate the use of OVE design and construction techniques, as was done in the Case Demonstration Studies. Instead, the Navy must rely entirely on the written requirements and the guidelines in the RFP.

OVE would probably work more effectively under the Navy's previous method of residential contracting where a separate A-E was contracted to complete the design, and then the design was released for contractors during the bidding stage. In this manner, a design could automatically include OVE design principles so that the contractor would have to build in accordance with them.

Unlike most other U.S. Navy construction contracts, however, housing is administered through the turnkey approach and it is unlikely that this approach will ever be changed. Working within the nature and framework of the turnkey approach, therefore, is the challenge of trying to adapt OVE design and construction techniques.

Summary

The Navy Housing Request For Proposal (RFP) is the standard contract document used by the Naval Facilities Engineering Command in family housing projects. The RFP contains specific design and construction criteria and guidelines in Section 2 that must be followed and satisfied by proposers. The selection of the successful proposer typically involves nine steps and is based upon the lowest dollar to quality point ratio among all proposers.

The RFP is unique in that it mandates a turnkey contract approach in which the successful proposer is both the designer and constructor. Due to this type of contract, the application of Optimum Value Engineering design and construction techniques will require special consideration and will not be as straightforward as the NAHB Affordable Housing Studies.

CHAPTER THREE

OVE DESIGN AND CONSTRUCTION PRINCIPLES

This chapter addresses the OVE design and construction techniques developed by the NAHB Research Foundation in the early 1980's as well as other innovative design and construction ideas that have been developed by other agencies, researchers, authors and residential designers. The eight major subdivisions identified by the initial OVE study will be examined individually.

Of the eight major subdivisions, Site Design and Development and Site Utilities and Storm Drainage will be examined in the greatest detail. The remaining six subdivisions consider design and construction of the housing unit and will be presented in a summary format of key ideas.

The discussion of the design and construction techniques is not intended to provide conclusive proof and evidence of their intent and success. This level of research and reporting has been previously completed by agencies such as HUD and NAHB. The intent in this chapter is to introduce the concepts so that the reader can understand them and then follow the application of these concepts to the Navy's housing contract Request For Proposal in Chapter Five.

Site Design and Development

In most residential developments, the area of site design and development provides the greatest potential for using OVE and other innovative ideas in order to reduce construction costs (7,8). Because it is the essential first step in planning and designing a development, it requires careful coordination and consideration of several key design elements.

NAHB has developed the following list of basic design requirements that should be considered in a site design (9):

1. Adequate space for all intended uses.
2. Space organized for the health, comfort and safety of residents.
3. Travel paths for pedestrians and vehicles efficiently designed and located.
4. Consideration of the natural environment, topography and current and projected land uses.
5. Creation of a varied and pleasing environment.
6. Flexibility, which permits the introduction of a variety of housing types and their setting.
7. Creation of an "image," distinctive in character and design, and blending housing and land in a way that appeals to the intended market.

Within this list, the arrangement of individual units and the layout of the street system are two areas where modifications for greater efficiency and reduced costs can be made to most conventional designs. These two areas of possible improvement can be broken down as follows:

Unit Arrangement:

1. Reduced lot sizes and setbacks
2. Clustering of units
3. Solar and wind orientation
4. Environmental enhancement

Street Layout:

1. Use of curvilinear streets
2. Reduced pavement widths
3. Reduction or elimination of curbs, gutters and sidewalks

Unit Arrangement

Reduced Lot Sizes and Setbacks. With typically high land costs, reduced lot sizes for an individual unit or group of units provide an automatic reduction in development costs. Front, rear and side lot clearances can be reduced and still provide suitable living space, provided they meet local ordinance requirements. One of the most common approaches to this idea has been the zero lot line development which is compared in Figure 4 to the conventional unit arrangement approach.

This approach places one of the side lot lines of the house directly on the property line, providing one

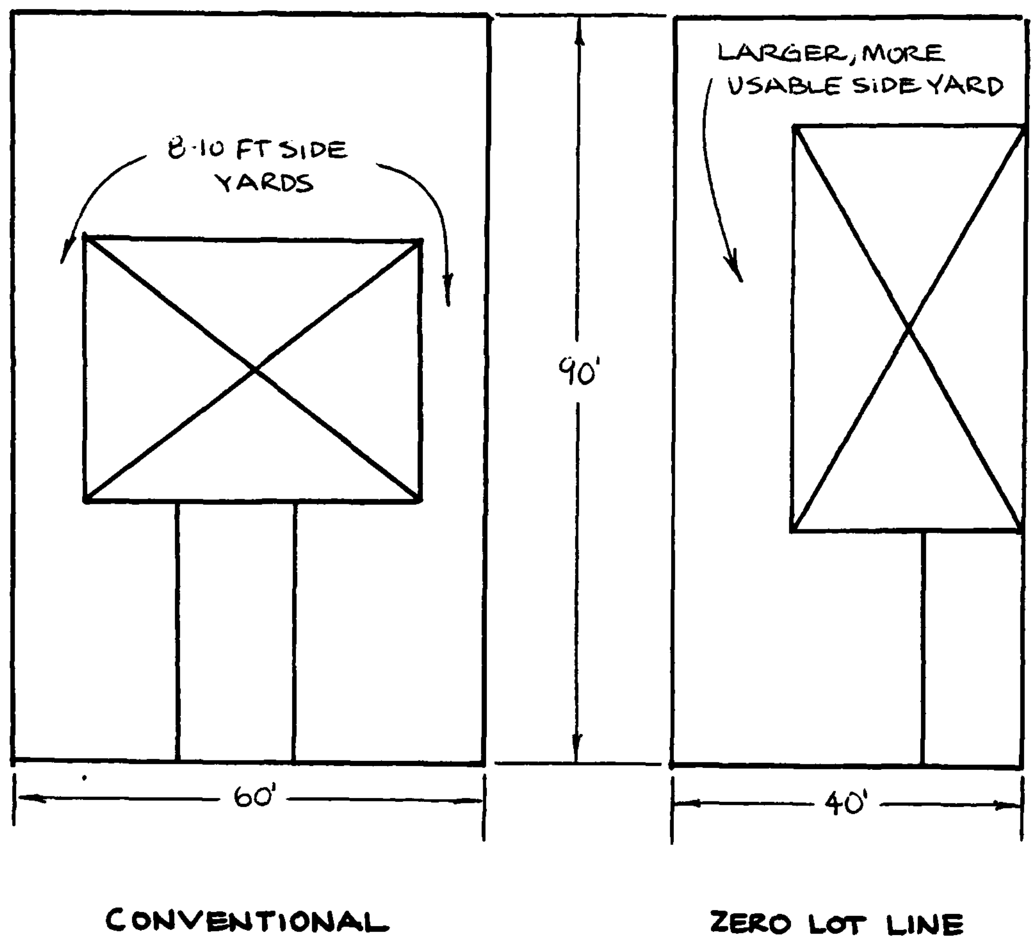


Figure 4. Conventional and Zero Lot Line Unit Arrangements. (From Land Development 2, NAHB.)

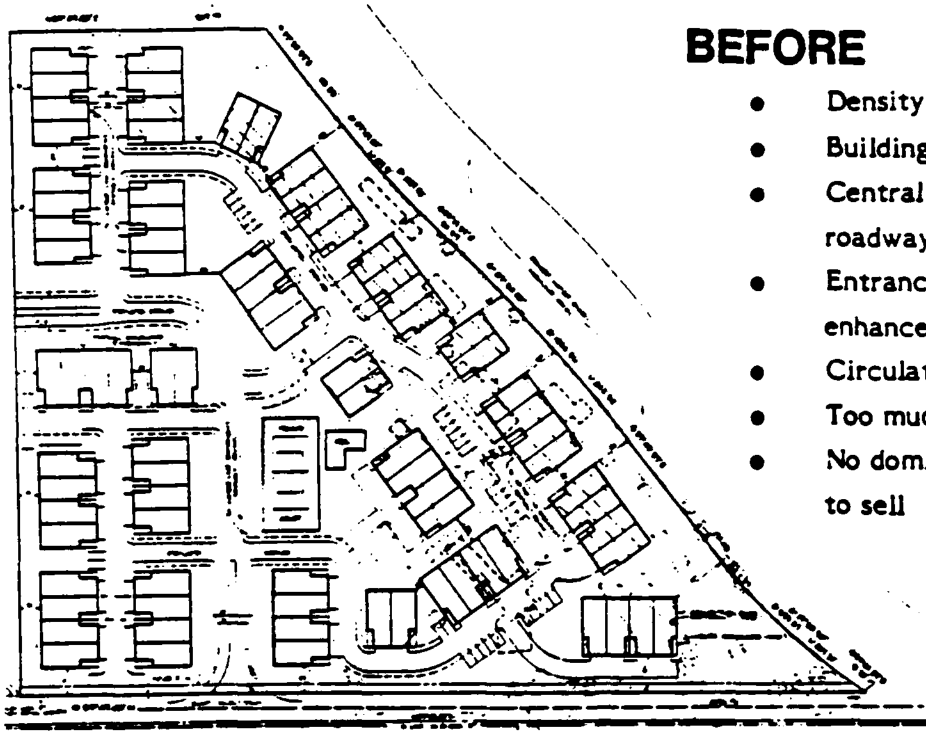
larger and more usable side yard rather than two smaller side yards as in the former arrangement. Zero lot line planning frequently includes the use of a patio, courtyard or atrium to provide a private outdoor space as the larger side yard.

Clustering of Units. Clustering is the grouping of multifamily units in arrangements about a central point. The objectives of clustering are (1) to hold down house prices by reducing development costs, (2) to encourage the building of townhouses, and (3) to foster a better environmental approach to development planning (11).

Additional benefits of clustering include dominant open spaces and features between units, increased privacy between clusters, reduced road length, reduced land clearing with preservation of surrounding trees and existing drainage patterns and a unique setting (11). Figure 5 provides a comparison of a conventional unit layout and a cluster unit arrangement.

Since most Navy housing is multifamily housing, the concept of clustering could be used effectively. Many Navy housing developments consist of long curvilinear streets and clustering can easily be substituted, resulting in lower site development and construction costs.

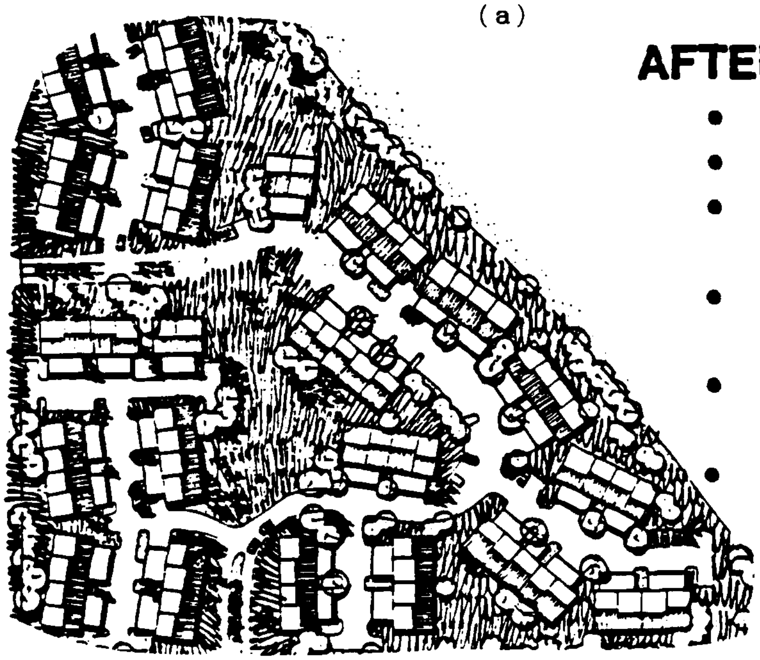
Solar and Wind Orientation. An energy efficient approach used in OVE design involves the consideration



BEFORE

- Density (82 d.u. - 9 ac.) 9 d.u./ac.
- Building arrangement rigid
- Central open space surrounded by roadways and parking areas
- Entrance drive views do not enhance development image
- Circulation patterns are confusing
- Too much road (length 2,700')
- No dominant open space amenity to sell

(a)



AFTER

- Density (82 d.u. - 9 ac.) 9 d.u./ac.
- Building arrangement
- Central open space located at the entrance, gives a sense of openness
- Circulation patterns very clear, organized and hierarchical
- Roadway length is reduced to 2,237 feet (463 feet less)
- Dominant open space or a feature

(b)

Figure 5. Unit Arrangements: (a) Conventional Townhouse Site Plan, (b) Clustered Townhouse Site Plan. (From Project Development Updates, NAHB.)

of solar and wind orientation. These two items are the most important factors in energy efficient design, resulting in significant energy savings during the summer and winter (13,14).

With the natural rising of the sun in the East and setting in the West, unit arrangements can be designed to make maximum use of the sun's lighting and heating.

Figure 6 shows how a unit situated on a longitudinal north-south axis will take advantage of morning sun from the east and evening sun from the west. This arrangement will allow the morning sun to enter front areas of the unit, typically the bedrooms or living room, and allow the evening sun to penetrate the rear areas of the unit, typically the kitchen, dining room and additional bedrooms.

Figure 7 illustrates the different sun angles in summer and winter and shows how a roof overhang will not interfere with heating in the winter and will assist in cooling in the summer.

In addition to the solar orientation of the unit, the location of windows is also very critical. Figure 6 illustrated how window placement on the east and west walls of a house provides direct lighting in the morning and evening hours of the day, respectively. It should also be noted that windows located on southern walls also provide light during the midday hours. The least

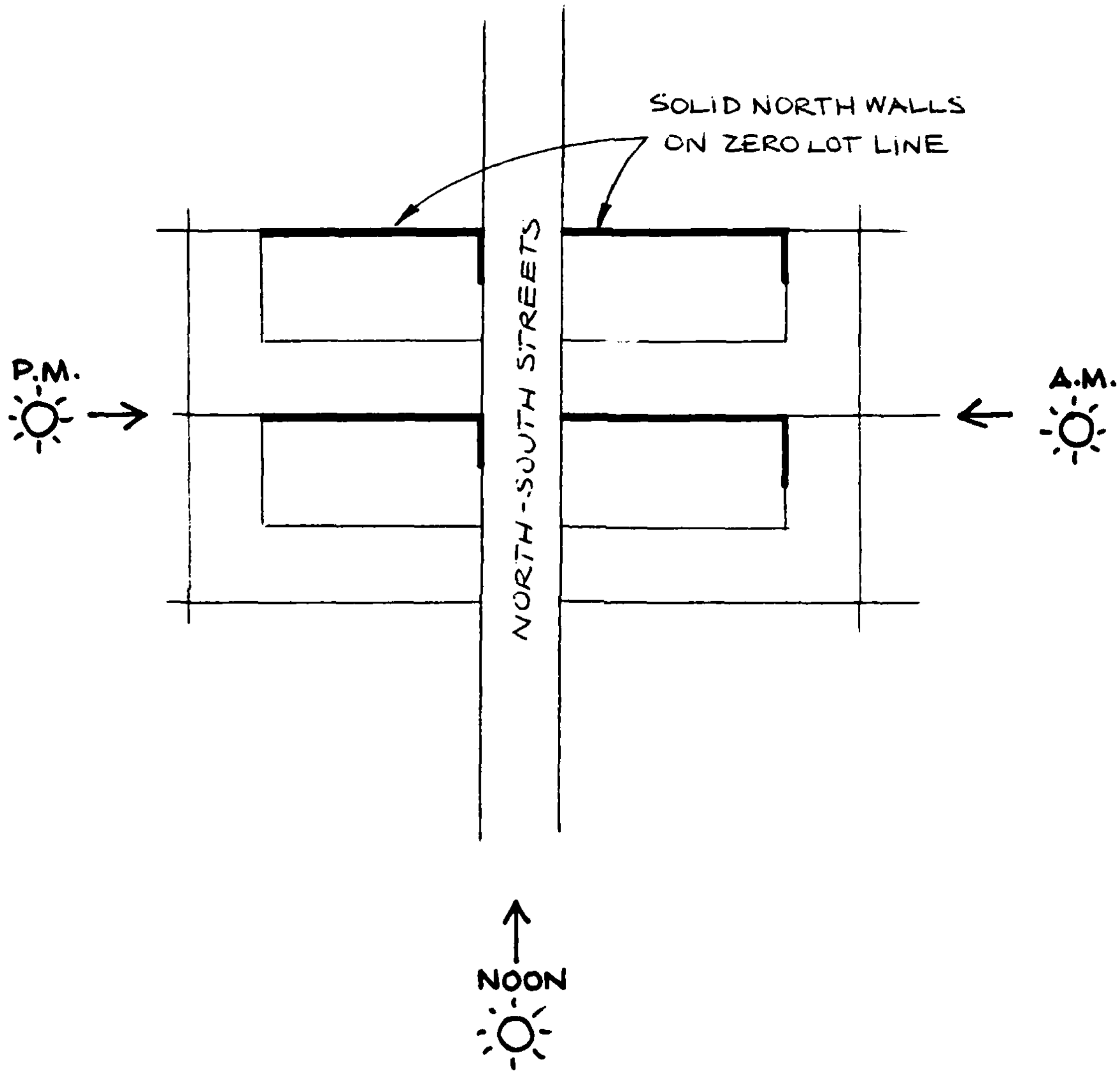


Figure 6. Solar Orientation.

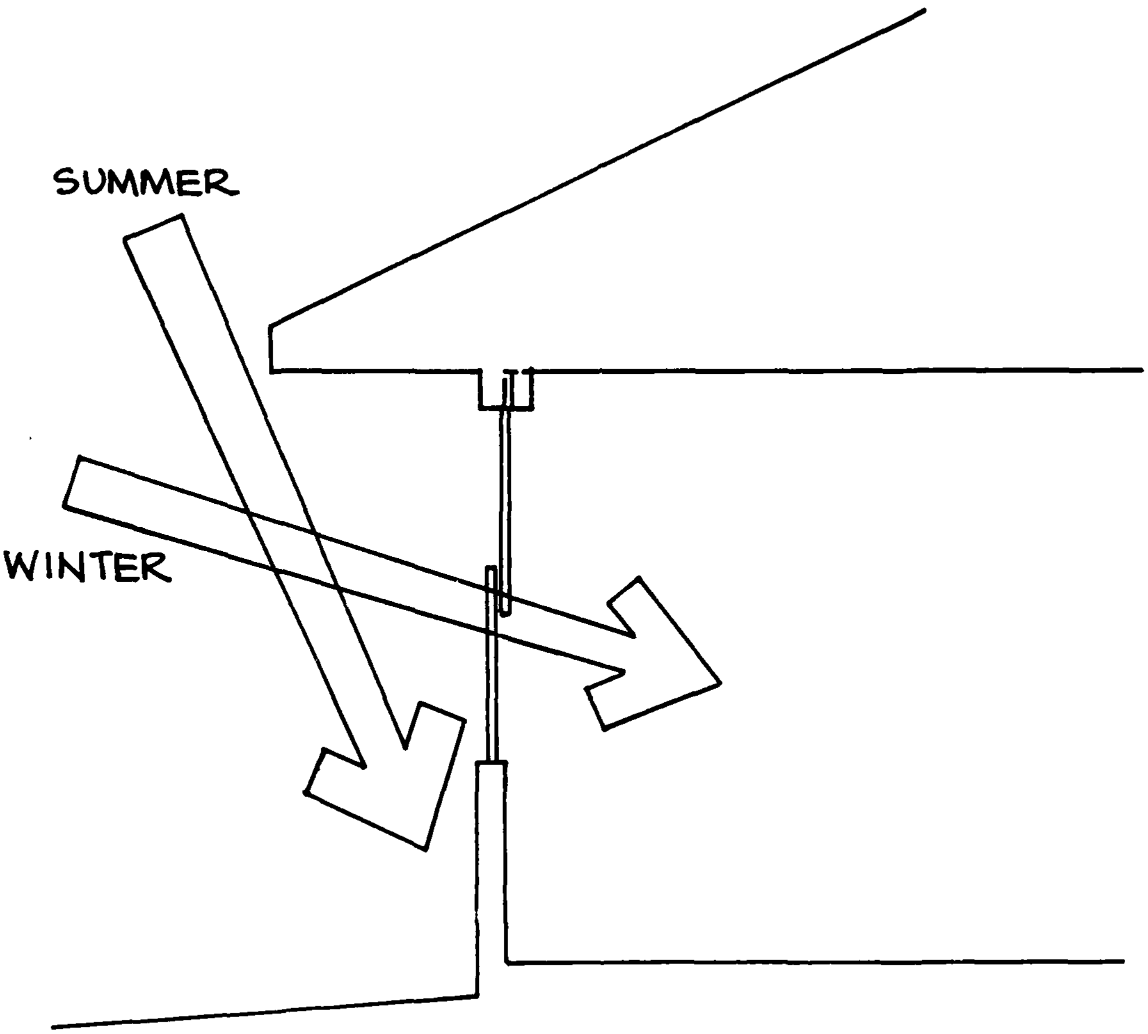


Figure 7. Passive Solar Design. (From Building Affordable Homes, HUD.)

effective location for windows is on northern walls where very limited direct lighting is available.

With a window most effectively located, Figure 8 explains how a typical glass window reflects, absorbs and transmits solar radiation. Approximately 80% of the solar radiation is transmitted through the glass panes, providing natural heating and lighting. The natural heating is a great asset during the cold winter months. Figure 7 depicted how unwanted heating in the summer can be avoided through the use of a roof overhang. An additional measure in reducing heating is through the use of reflective window films (solar films) or bronze tinted glazing.

A less obvious and often disregarded environmental consideration is that of wind. Similar to solar orientation, unit arrangements that consider wind orientation can also realize benefits in both the summer and winter. In the summer, natural ventilation and cooling is possible from typically southern breezes. Winter, however, provides cold winter winds that should be deflected away from the unit.

Figure 9 illustrates the different directions of typical winter and summer winds and provides one possible arrangement of units that will guard against cold winter winds and take some advantage of summer breezes (15). It is noted that solid house walls, i.e.

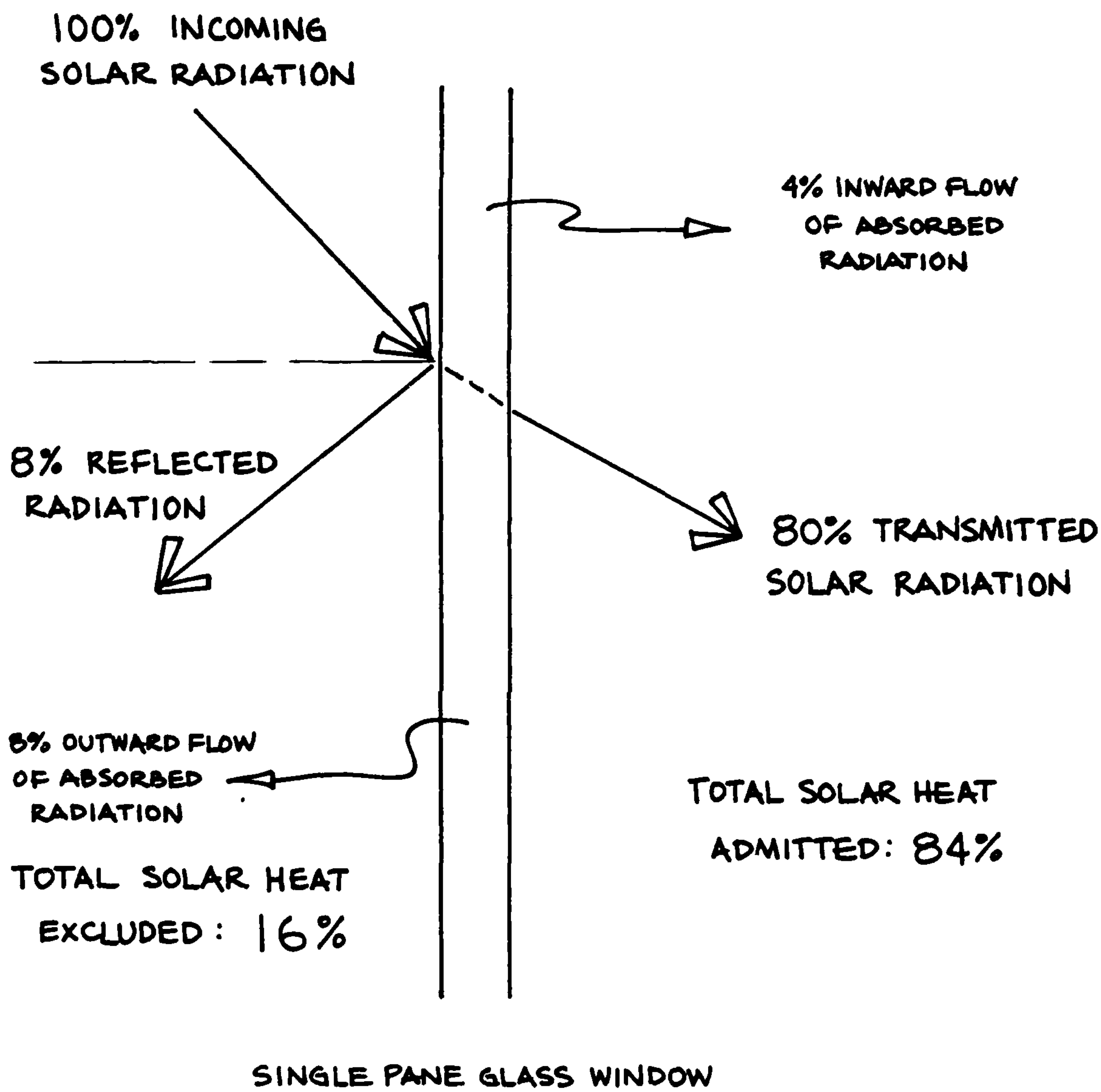


Figure 8. Solar Radiation Effects on a Glass Window. (From The Architect's Guide to Energy Conservation, Jarmul.)

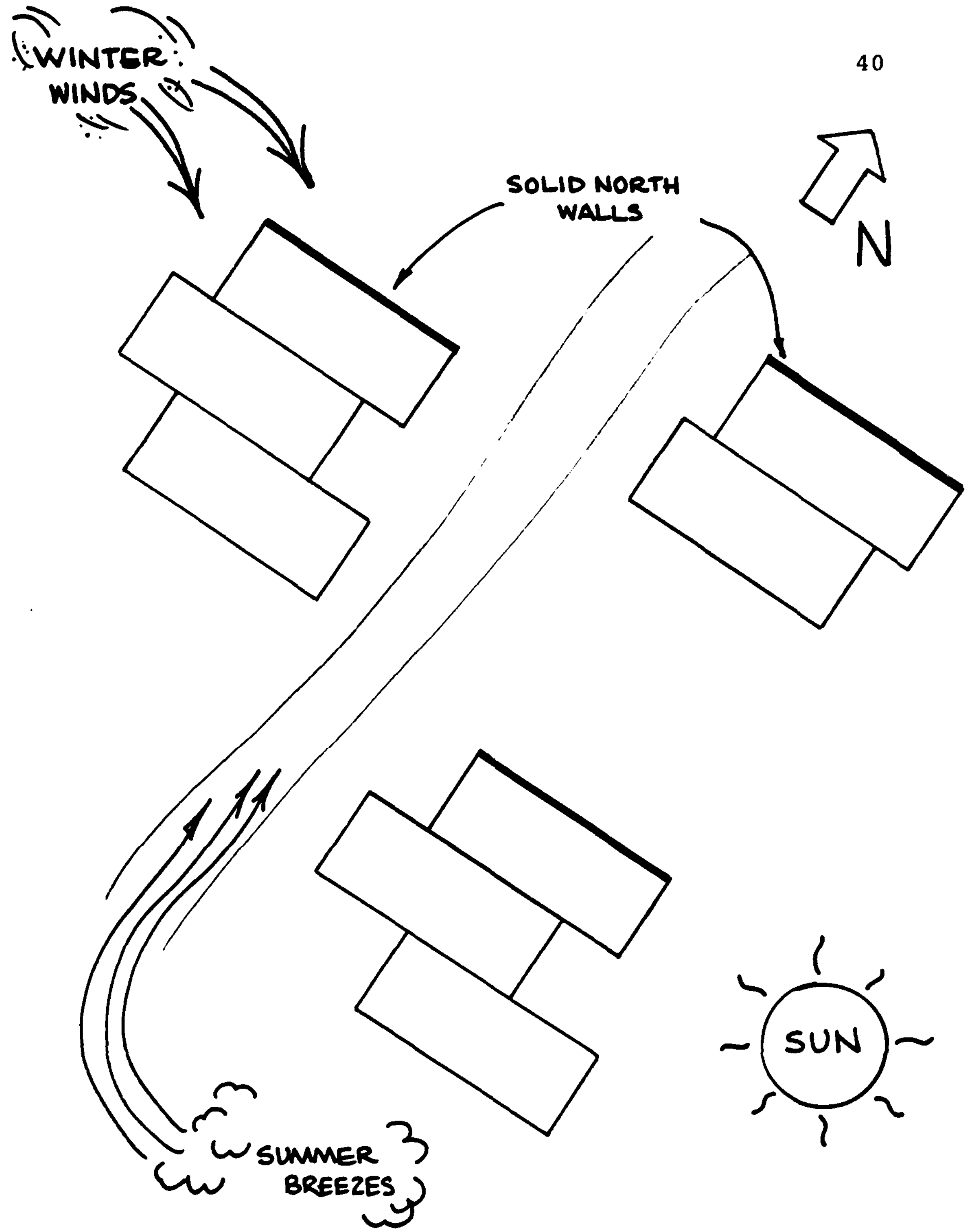


Figure 9. Typical Winter and Summer Wind Patterns in a Temperate Region. (From Zero Lot Line Housing, Jensen.)

no windows, on the northern face of the house is one key safeguard against unwanted winter air infiltration. With reduced infiltration, less heat is, therefore, required to warm and maintain a constant indoor temperature.

In addition to carefully selected unit arrangements, the use of windbreaks provides another way of reducing air infiltration. A windbreak is typically a fence or row of trees or shrubs that reduces air infiltration through windows by reducing the wind pressure. A windbreak can also be a row of tall trees bordering the property or unit that deflects the breezes over the unit (13).

Windbreaks are naturally available from existing trees that border or surround a unit or cluster of units. The most efficient location of units along a tree line is at a distance of two times the height of the building. At this spacing, winds will normally be deflected over the building, eliminating pushing on the windward side and pulling on the leeward side, which, otherwise, creates pressure zones around a unit and results in increased air infiltration (13).

In summary, the solar orientation of the unit and the location of windows are two key design factors to consider in OVE site design. Orientation and wind location are interrelated and it is important to note that benefits are possible during the summer and winter. Wind orientation is another environmental factor to consider during site design, as proper planning can take advantage of cooling summer breezes and protect against cold winter winds.

Environmental Enhancement. In addition to wanting a well designed and energy efficient home, most individuals prefer an attractive environment to live in. Whether single family detached homes or clustered multifamily units, there are several ways in which the natural surroundings can be preserved or enhanced.

The natural surroundings in a development should be considered first prior to incorporating specific OVE design ideas. Views of water, mountains and other sights should be maximized so that the greatest number of units can benefit from these natural assets. While this consideration is not necessarily associated with OVE design, it does increase the appeal of the unit and lot.

As previously stated, clustering of units automatically reduces land clearing and will preserve existing stands of trees and other vegetation. With more of the existing foliage preserved, more of the original drainage paths are also maintained and the existing vegetation continues to thrive.

In many cases, environmental enhancement is related to energy design considerations and the type of construction materials used. For example, grass is 33% cooler than pavement when both are exposed to sunlight and would, therefore, be a preferred type of exterior covering next to a unit, especially next to windows. Vegetation naturally blocks solar radiation and reduces heat loads on exposed surfaces, whereas concrete and asphalt absorb and then transmit heat. This is the same rationale used in selecting a white roof over a dark roof as it is normally 10-20% cooler (16). Table 1 provides some typical temperatures of exterior surfaces.

TABLE 1

Average Temperatures of Exterior Surfaces

Item	Avg. Temp. (F)
Trees	80
Grass Lawn	111
Wall Surface	130
Asphalt	160

(From *Energy Efficient Site Design*)

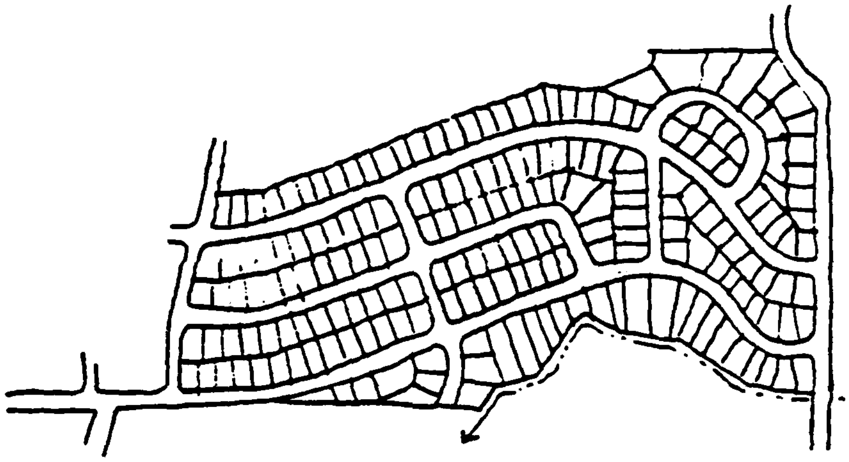
What constitutes a good site design will vary from developer to developer and resident to resident. Certain factors are constant, however, and involve those of comfort, appeal and good taste. With attention given to the environmental factors, those existing and those to be modified, a site design can be greatly affected in terms of visual impact and appeal. OVE design considers these natural assets and promotes the preservation and use of these assets as cost saving measures in site design and construction.

Street Layout

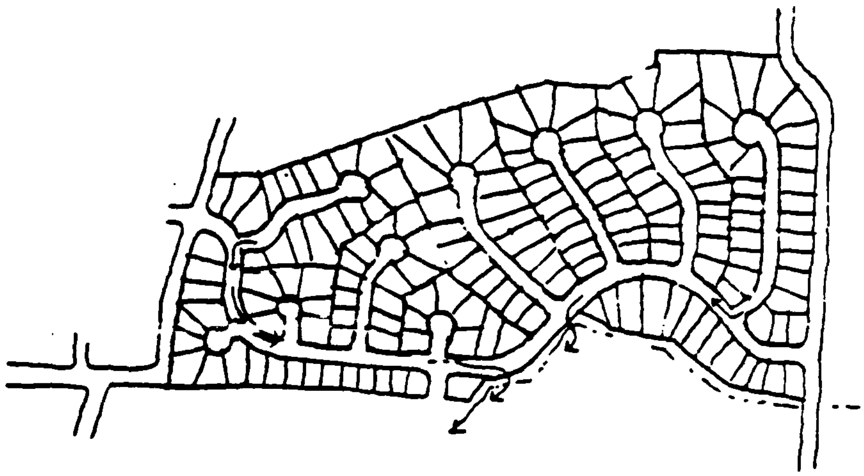
Curvilinear Streets. As previously discussed, site development is an expensive endeavor, yet new design techniques can be used to reduce these development costs. Two readily available modifications of the site's street system include the use of curvilinear streets and reduced pavement widths.

Many conventional road system designs use a grid consisting of mostly long straight streets intersecting at right angles. This arrangement has two disadvantages; one is higher construction costs due to greater road lengths and the other is that an unattractive setting for a residential development is created. Curvilinear streets provide a solution to both of these problems.

Figure 10 illustrates these two street layout systems. An additional advantage of the curvilinear system is that it primarily serves the houses located in the development and does not promote through traffic, as the grid network commonly does (12). It should be noted that a curvilinear street system complements a



Conventional Network



Curvilinear Network

Figure 10. Conventional and Curvilinear Street Networks. (From *Project Development Updates*, NAHB.)

development of clustered units. With clustered units, the length of pavement is further reduced and construction costs can be lowered to an optimum level.

Reduced Pavement Widths. While street lengths can be reduced by using curvilinear streets and clustered units, street widths can also be reduced.

A conventional and a modified street section are presented in Figure 11. The conventional section provides a forty foot pavement width, while the modified section proposes a twenty-six foot pavement width. In some cases, such as in the NAHB Affordable Housing Studies, pavement widths were reduced to as low as eighteen to twenty feet.

NAHB has identified several key design factors (3):

1. Widths should be based on functional needs.
2. Municipal codes should be reviewed in light of present day objectives.
3. Excessive width adds cost, detracts from human scale and neighborhood quality.

Since different streets must serve different purposes, it is possible to develop a hierarchy of street classifications that can be followed in a site design. Table 2 provides such a hierarchy and can be used as a reference during the street layout and design phase.

The benefits of designing to a hierarchy of streets can result in the following significant savings (4):

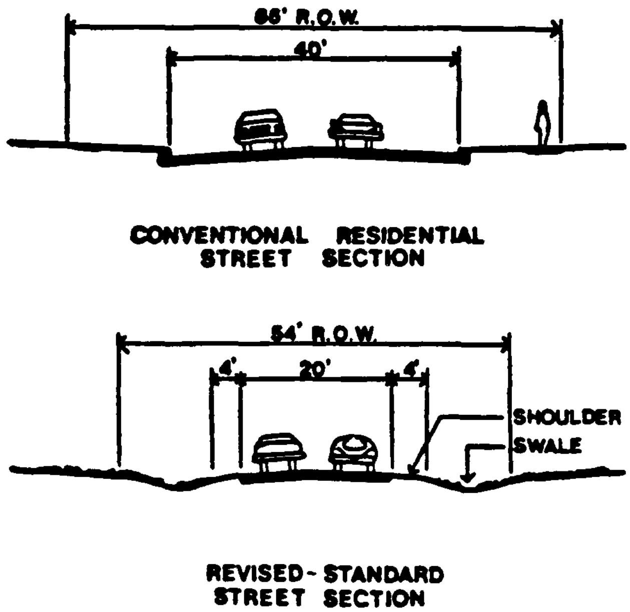


Figure 11. Conventional and Modified Residential Street Sections. (From Project Development Updates, NAHB.)

TABLE 2

Hierarchy of Street Classifications

	Place	Lane	Sub-Collector	Collector	Arterial
Service	Very Light	Light	Local Traffic	Local & Thru	Thru Only
Traffic ADT (1)	0-200	201-500	501-1000	1001-3000	3001 +
Pavement Width					
No parking	18′	18′	26′ (2)	28′	(3)
Parking 1 side	18′	18′	28′	36′	(3)
Parking 2 sides	26′	26′	36′	36′	(3)
R.O.W. WIDTH	24′-30′	24′-30′	44′-60′	44′-60′	(3)
Street Slope (4)	0.5% to 15.0%	0.5% to 10.0%	0.5% to 10.0%	0.5% to 8.0%	(3)
Maximum Speed	20 mph	25 mph	30 mph	35 mph	(3)

(1) Average Daily Traffic
(2) Two nine-foot moving lanes plus one eight-foot emergency stopping lane.
(3) Arterial streets shall be designed for specific traffic and roadway conditions as well as other related factors.
(4) Adequate cross slope of at least 2 percent is required to prevent ponding.

(From Building Affordable Homes, HUD.)

1. Less use of land and paving due to narrower roads and streets.

2. The elimination of curbs and gutters in minor streets like lanes and places.

3. Wide streets require more clearing and grading and destroy more natural resources.

4. More paved areas increase run-off and add cost to storm drainage systems.

5. More space dedicated for individual lots or open public spaces.

It is important to note that the reduced street width must still be able to support all expected functions, including large moving vans and emergency vehicles. The objective is to reduce widths and costs where possible and not to interfere with the intended purpose of the street.

Reduction or Elimination of Curbs, Gutters and Sidewalks. Curbs, gutters and sidewalks do serve an important function in areas of high traffic volume and excessive annual precipitation. There are many cases, however, where curbs, gutters and sidewalks can be reduced or eliminated.

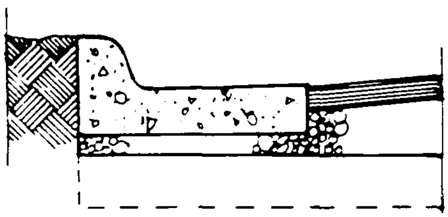
Within an established hierarchy of streets, minor streets, such as lanes and places, do not normally require curbs, gutters and sidewalks since they do not have to be built to the higher standards of major roads. Therefore, the curbs and gutters can be eliminated without detriment to the development. In most cases, however, the use of sidewalks as a safety convenience should still be considered.

Figure 12 illustrates four common curb and gutter designs. The most expensive is the vertical curb. That design is sometimes necessary, especially on major collector and arterial roads. If practical, rolled curbs or no curbs, with a grassy swale, should be considered in lieu of the vertical curb.

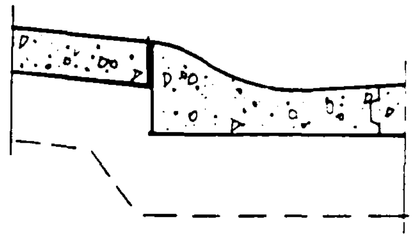
Sidewalks are sometimes desirable and necessary, yet their use, too, can be reduced. In particular, sidewalks on both sides of the street are seldom necessary and typical of an excessive design feature that provides little extra use. Realistic evaluation of design requirements should indicate if sidewalks are required at all, and if so, along which streets. Great care and planning is required to determine the location and extent of sidewalks to minimize development costs and maximize their usefulness (4).

Site Utilities and Storm Drainage

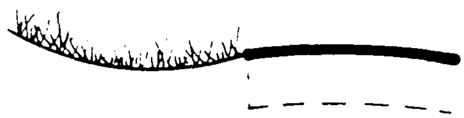
As a part of the overall site development process, site utilities and storm drainage is also an area in which OVE and innovative design modifications can be used. Many of these modifications are the result of research conducted by the U.S. Department of Housing and Urban Development. The following systems are involved:



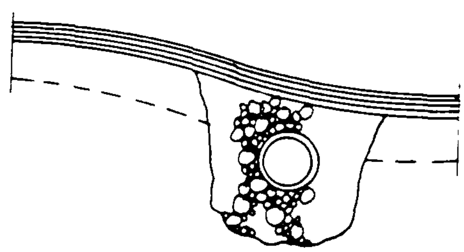
(a) Vertical curb



(b) Rolled curb blending with driveway



(c) No curb-grassy swale meets roadside



(d) Culvert carries water under driveway

Figure 12. Common Curb and Gutter Designs. (From Building Affordable Homes, HUD.)

1. Water System
2. Sewer System
3. Electrical System
4. Natural Gas System
5. Storm Drainage System

Each of these systems will be discussed in terms of proven cost saving design and construction techniques.

Water System

Water Main Design. Water systems should be designed for the average daily demand (ADD) and peak usage in a development. The ADD will vary depending on the average rainfall, family size and consumption and activities such as car washing and lawn sprinkling. As a minimum, the system must provide safe, potable water under constant pressure (3).

One of the major factors in a water system design is the allowance for fire protection. While this requirement cannot be eliminated, water main sizing can normally be reduced on lines that do not support fire protection. Without fire protection requirements, the water main size is based solely on residential demand and is an amount much less that that required for fire protection.

In most cases, six inch waterlines are installed where residential use and fire protection are required. If fire protection is not included on a line, then these lines can be downsized to two, three or four inches. With a smaller waterline required, material and installation costs are reduced (17).

Multiple Water Services From a Common Tap. Especially adaptive for multifamily housing, water service can be supplied to more than one residence from a common tap (17). This saves material, excavation and backfill costs and still provides the required water service per unit. Figure 13 provides one possible arrangement using a common tap and single lateral.

Polyvinyl Chloride Pipe (PVC). With an established record of durability in water and sewer systems, PVC pipe offers the advantages of being lightweight, easier to install and corrosion resistant. With proper trenching, bedding and backfill, PVC water and sewer lines can last indefinitely.

Plastic Pipe or Tubing for Service Lines. Instead of using copper or galvanized iron pipe for home service lines, plastic pipe or tubing can be substituted. These materials include polyvinyl chloride (PVC), polyethylene or polybutylene and have the advantages of being lightweight, flexible, easier to install and resistant to electrolytic and galvanic corrosion.

When using plastic pipe or tubing, careful consideration must be given to suitable backfill

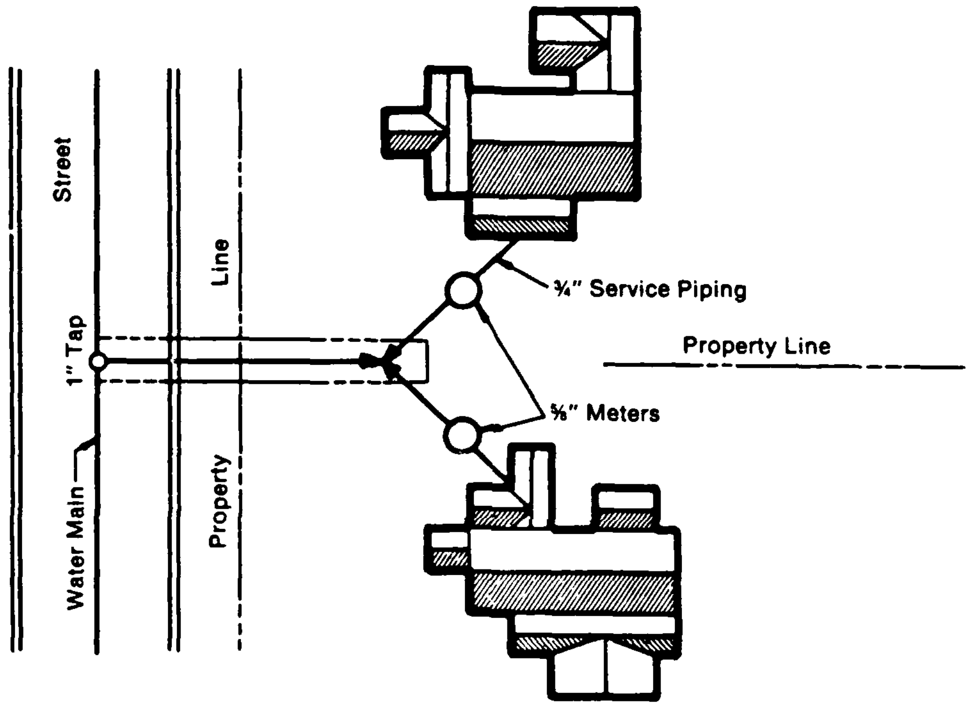


Figure 13. Multiple Water Service Connections From a Single Lateral. (From <u>Innovative Site Utility Installations</u>, HUD.)

material that does not contain rocks. All lines must also be installed below the frost line (17).

Blow-offs Versus Hydrants. On waterlines that support fire protection, fire hydrants also provide a means of flushing the lines to remove sediment or contaminated water. On lines not supporting fire protection, a standard blow-off valve at the low points on the line can serve the purpose of flushing. A blow-off valve will typically cost \$60-\$100 less than a fire hydrant (17). This can result in a significant savings when there are many fire hydrant locations on a site. Figure 14 provides an example of a typical water line blow-off valve.

Eliminate Curb Stops. Curb stops have historically served two main purposes (17):

1. When water meters are located inside a unit, curb stops provide a means of turning the water off without entering the unit.

2. Curb stops allow main line taps to be made before meter boxes and yokes are installed.

Many municipalities are not using curb stops any longer since water meters are normally installed outside of the unit in a meter box. In addition, proper planning during the utility installation phase will not require a temporary valve such as the curb stop. NAHB suggests that curb stops should be eliminated in order to avoid additional maintenance problems and hazardous tampering with the water supply.

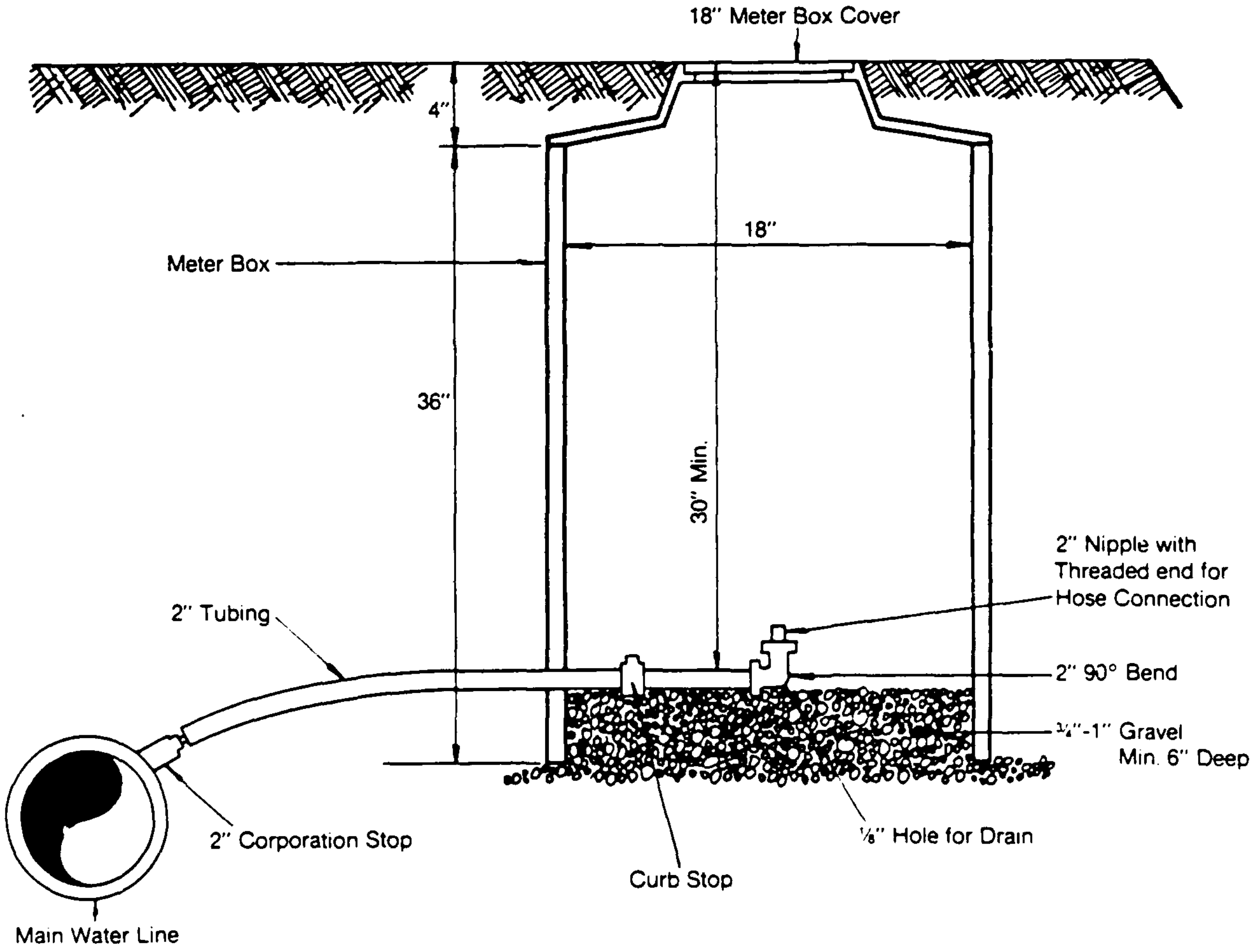


Figure 14. Standard Water Line Blow-Off Valve. (From Innovative Site Utility Installations, HUD.)

Joint Trenching of Water and Sewer Lines. Practice has long dictated that water and sewer lines be separated by a minimum horizontal distance of ten feet. With improved materials, installation techniques and thorough inspection prior to acceptance by the jurisdiction, this requirement could be reduced to allow joint trenching, according to OVE findings.

Figure 15 illustrates an arrangement where the water line is located a minimum of twelve inches above the sewer line with a horizontal separation of a mimimum eighteen inches. With careful installation, proper backfilling and compaction, quality control testing and improved materials, such as PVC pipe, this arrangement should provide the required safety factor and result in lower excavation and installation costs (17).

Sewer System

Curvilinear Sewer Lines. While still a relatively new and unaccepted practice, the use of curvilinear sewers does have several key advantages. Curved sewers can be constructed of rigid or flexible pipe. Rigid pipe (asbestos cement, concrete, ductile iron, vitrified clay) is installed by deflecting the pipe joint from a straight position and flexible pipe (PVC) is deflected by bending the pipe itself. Figure 16 indicates the allowable bending radii of PVC pipe.

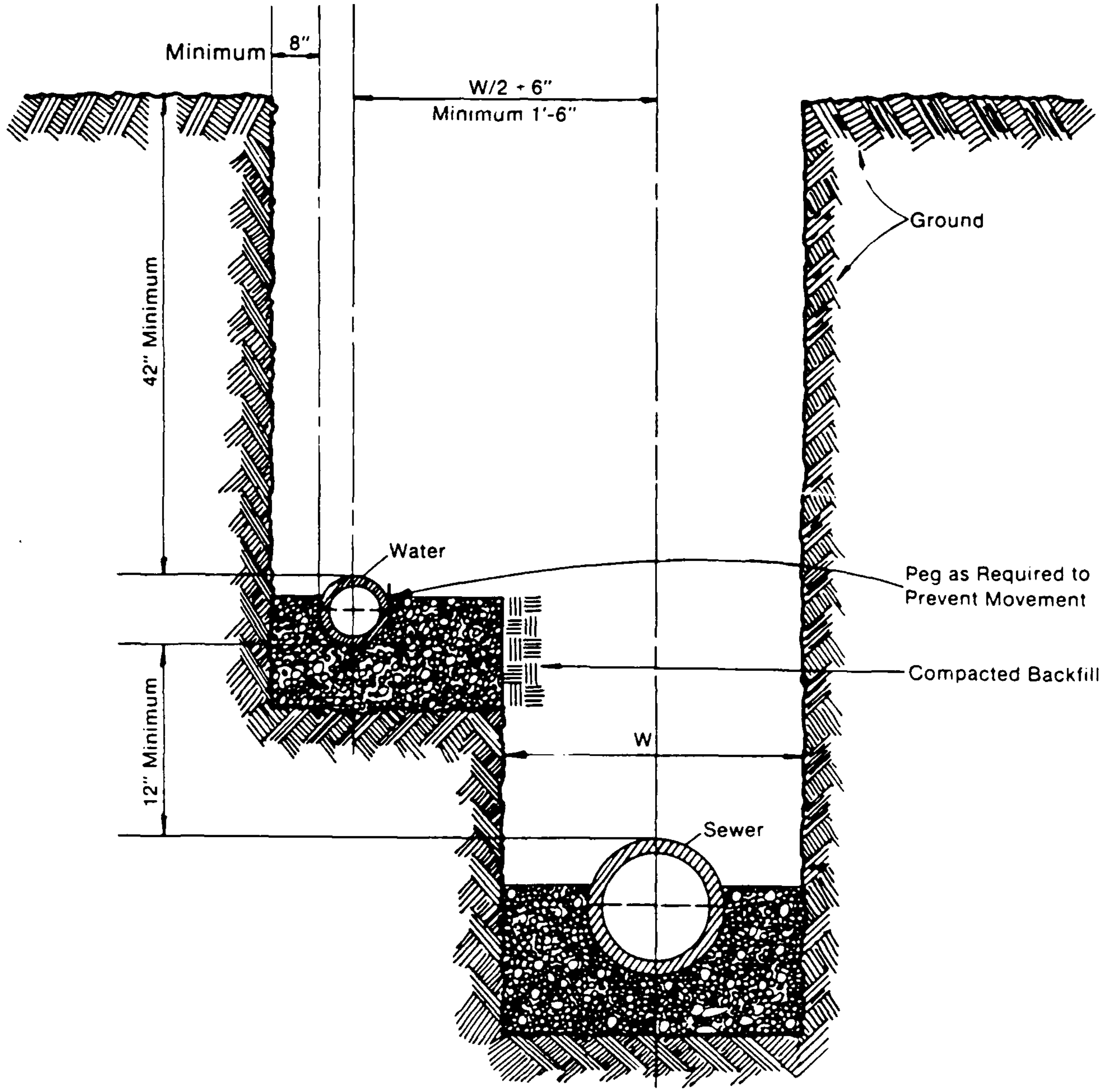
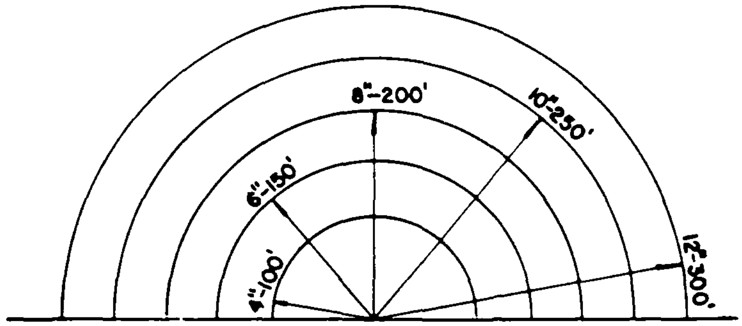


Figure 15. Typical Ditch Section for Common Trenching of Water and Sewer Lines. (From Innovative Site Utility Installations, HUD.)



Pipe Size	Section Length, Ft.	Approximate Linear Offset at Minimum Radii, Inches	Cantilever Force at End of Pipe to Accomplish Minimum Radii, Lbs.
4	20	24	6
6	20	16	20
8	20	12	48
10	20	12	95

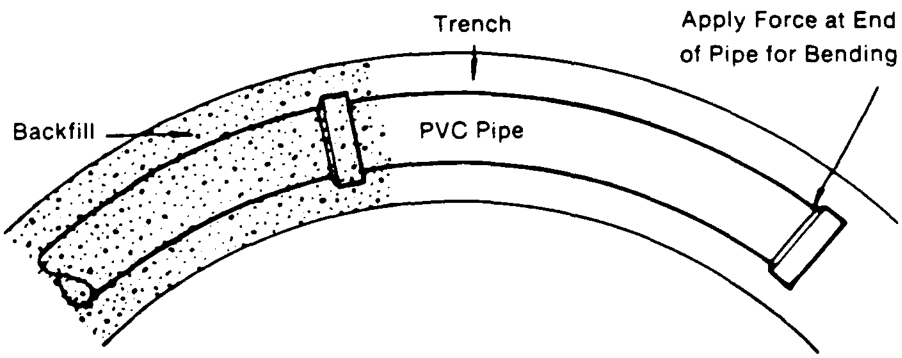


Figure 16. Allowable Minimum Radii for Bending PVC Pipe. (From Innovative Site Utility Installations, HUD.)

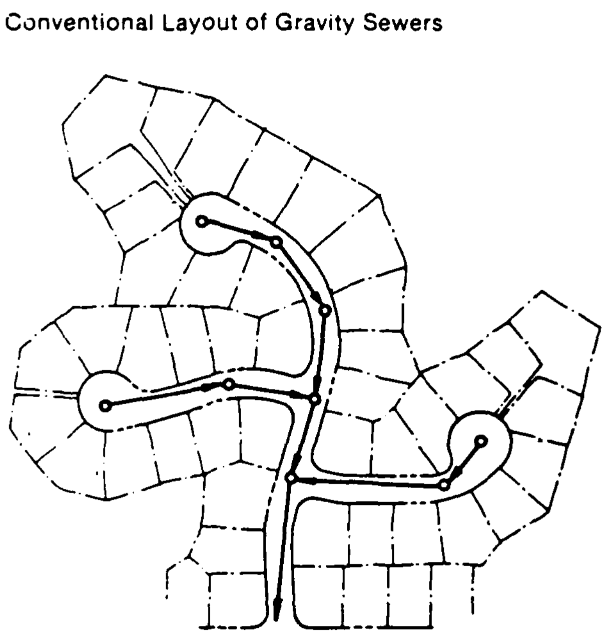
With a curved sewer, fewer manholes are needed since there are fewer changes in horizontal direction. This can result in a savings of approximately $1000-$1500 per manhole not used.

The curved alignment can normally follow the centerline of the street and thereby be easier to install and avoid other utilities. In addition, the design can better follow topographic contours, maintain a uniform grade and improve hydraulic efficiency (3,17). Figure 17 illustrates the design and cost comparison of a conventional layout and curvilinear layout of gravity sewers.

Reduced Diameter Gravity Sewer Lines. Many jurisdictions require a gravity sewer collector to be eight inches in diameter in order to prevent clogging and to allow minimum flow velocities (two fps) to be maintained at moderate slopes (0.40'/100')(17).

For other than collector lines, smaller diameter lines, such as six inch and four inch, can be used on shorter streets, cul-de-sacs or dead ends. If no future development is planned in these areas, then these smaller diameter lines can sufficiently handle the sewage (17).

Common Sewer Service Laterals. The same principle of a common tap for multiple water services can be used with sewer lines. A common sewer service lateral can



	Line Footage	Manholes	Estimated Cost, Installed $*
Conventional Alignment	1240	9	38,300
Curved Alignment	1180	5	31,100
		Savings	7,200

*Unit Cost: 8" Sewer Line @ $20 per Linear Foot
Manholes @ $1500 each

Figure 17. Conventional Gravity Sewer Layout Versus Curvilinear Design. (From Innovative Site Utility Installations, HUD.)

also be used for multifamily units. With the common sewer lateral, less excavation, backfill, pipe material and fittings are needed.

Increased Spacing Between Manholes. Current practice and codes limit the maximum spacing of sewer manholes under fifteen inches in diameter to 400 feet. This standard was based on the quality of construction materials and the type of cleaning equipment used to clear obstructions in the sewer lines that existed many years ago.

Current methods and materials, however, can allow spacing up to 600-800 feet between manholes. The key limiting factor is the type of cleaning equipment used by the jurisdiction. In cases where cleaning equipment can reach up to 400 feet in one direction, 800 ft. spacing between manholes can be used effectively.

Cleanouts Versus Manholes. In many cases, cleanouts can be substituted for manholes on sewer lines and still provide access for periodic cleaning. Although cleanouts are not recommended replacements for manholes in all cases, they can be used to reduce construction costs in the following applications (17):

1. Terminal lines - On short lines between 200 and 300 feet, it may be more practical to install cleanouts instead of manholes since maintenance access is still available through the cleanout on the top end of the line (see Figure 18).

2. Line Repairs - Cleanouts can be substituted for some manholes on existing lines that require repairs.

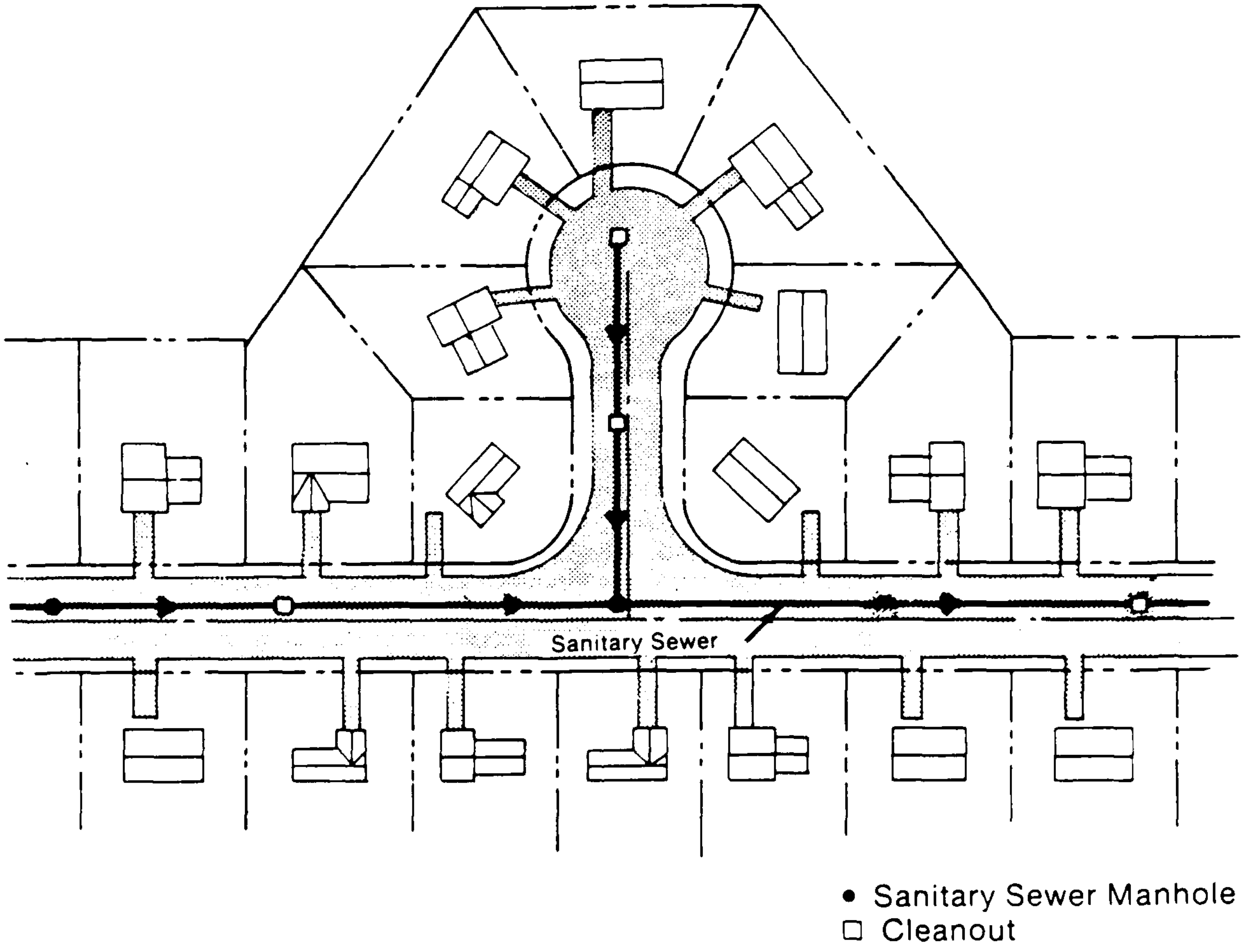


Figure 18. Typical Sanitary Sewer Lines With Cleanouts. (From Innovative Site Utility Installations, HUD.)

3. Sewers in Flood-Prone Areas - Where watertight manholes are required in low-lying areas, cleanouts can be substituted since they are not as susceptible to infiltration and are less expensive to install.

4. Rocky Terrain - Using cleanouts in lieu of manholes in rocky terrain can significantly reduce excavation and save installation time.

5. Short Sewer Lines - Cleanouts can be used in place of several manholes on sewer systems where many horizontal bends require manholes.

Electrical System

Common Trenching of Electrical, Telephone, Cable Television and Natural Gas Lines. Joint trenching has become a very common and widely accepted practice in many communities, providing the following advantages (17):

1. Maximum use of land with narrower utility easements.

2. Reduced clearing, grubbing and excavation.

3. Coordination of several utilities results in a shorter time for installation.

Utility companies across the nation, and in large cities such as Houston, Cincinnati, Tacoma, Baltimore, and Miami, are using common trenching. One arrangement, used by San Diego County, CA, is shown in Figure 19.

Common Construction/Ownership of Utility Poles and Trenches. Although not a widespread practice at this time, coordination between utility companies on the installation and maintenance of utility poles and trenches can lower construction and operating costs.

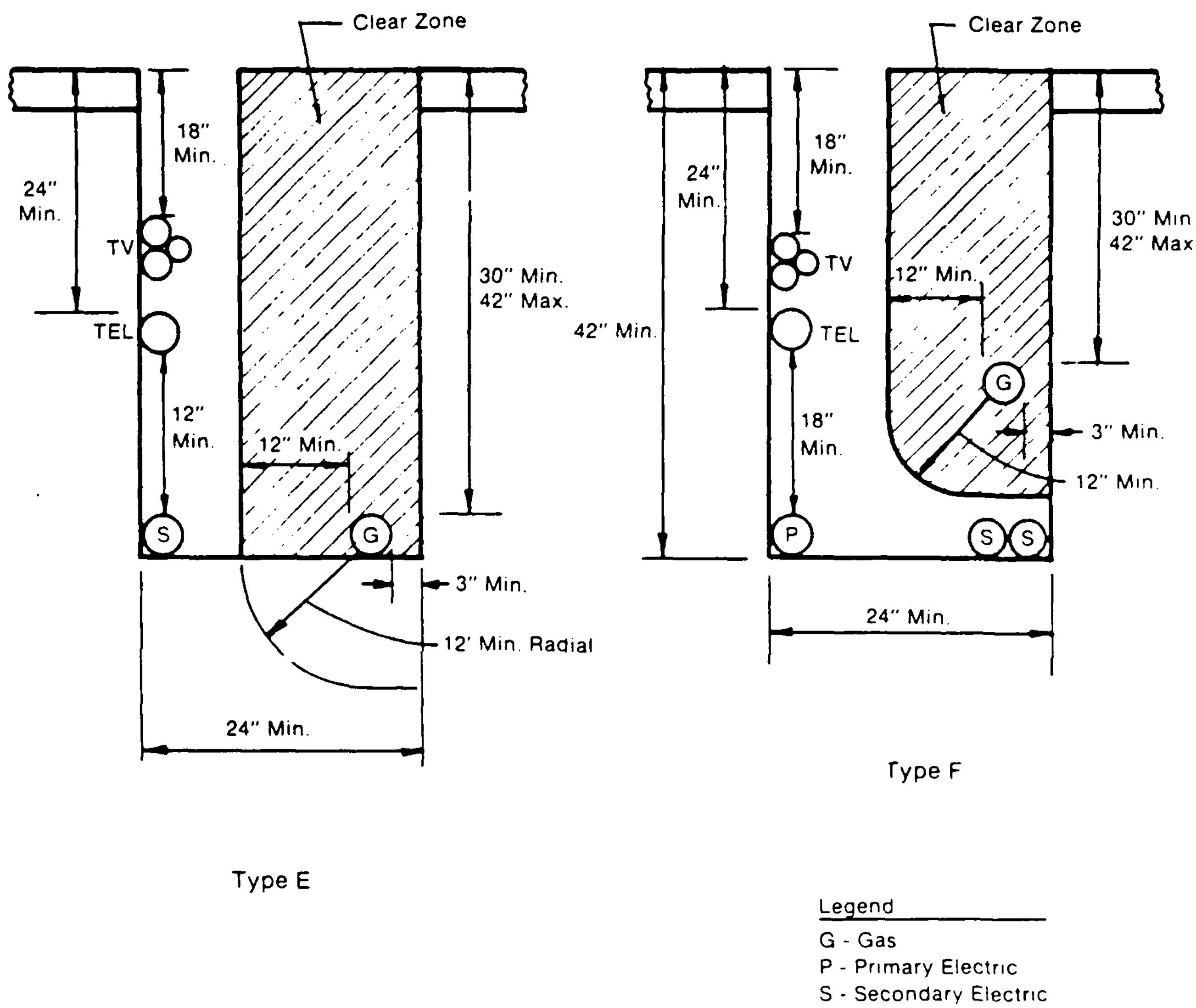


Figure 19. Joint Trench Utilities Location. (From Innovative Site Utilities Installations, HUD.)

Through the use of ownership and maintenance agreements, utility companies can install their utilities at the same time, resulting in less time required for completion.

Direct Burial Cable. For underground electrical systems, direct burial cable can be installed by trenching or plowing the electrical cable directly into the ground with minimal surface disturbance. The alternative involves costly and time consuming installation of conduits or ducts for the electrical lines. For areas with intended future growth, direct burial cable installation is not as advantageous as conduits and ducts since additional excavation is required for expansion.

The installation of direct burial cables and an empty PVC conduit side by side is one solution to this problem. If the cable is damaged, or expansion is required, another cable can be pulled through the parallel conduit. Figure 20 illustrates the two alternatives for underground electrical system installation.

Installation of Underground Lines Prior to Curb Construction. Underground electrical lines can be installed before curbs, gutters and sidewalks are constructed to prevent damage and necessary rework (17).

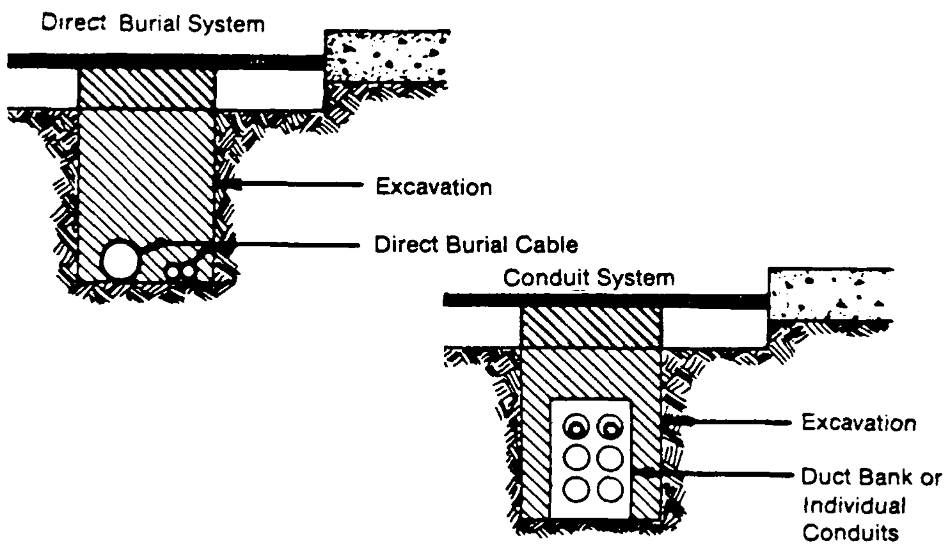


Figure 20. Alternatives for Underground Electrical Installation. (From Innovative Site Utilities Installations, HUD.)

Natural Gas System

Plastic Pipe for Natural Gas Lines. Of the gas companies surveyed by HUD, the majority stated that the use of plastic pipe instead of steel pipe has been the single largest cost saving measure in the industry (approximately 30% lower costs). Many of these companies presently use direct burial plastic pipe for new lines less than six inches in diameter and operating at pressures under sixty psi. The plastic pipe can consist of the following materials: polyethylene (PE), polyvinyl chloride (PVC), cellulose acetate butyrate (CAB) and epoxy reinforced fiberglass (EFG). The advantages of plastic pipe include lower material costs, fewer joints, smaller construction equipment for installation and corrosion resistance (17).

Joint Trenching. Natural gas lines can be included in the same trench as the electrical utilities as indicated in Figure 18.

Common or Gang Services. Ideal for rowhouses or multifamily units, a common gas service line can feed into a single manifold system with individual gas meters. This arrangement is less expensive to install than running separate service lines from the gas main to each unit (17).

Storm Drainage System

Storm Water Management. The conventional practice for many years in storm water management was to collect the water and transport it away from a site as quickly as possible. This practice involved large, complex drainage systems that were expensive to build and frequently caused flooding or erosion at the downstream location. Newer methods developed and used by HUD, NAHB and private developers now involve water collection, retention and slow release from the site.

With this method, a retention pond is constructed and located on site at a safe distance away from the development's lots. The retention pond, at the low point of the surrounding area, is fed by a storm drainage system that typically consists of smaller, less expensive to build culverts, catch basins and drainage lines (4).

With a retention pond, drainage system velocities can be reduced which results in reduced system sizes and requirements. Beyond the retention pond, a slow release outlet, such as a spillway, can be constructed so that the accumulated water eventually feeds into the municipal storm sewer system, if one exists. See Figure 21.

Natural Drainage and Unpaved Swales. With the previously mentioned use of clustered homes and shorter

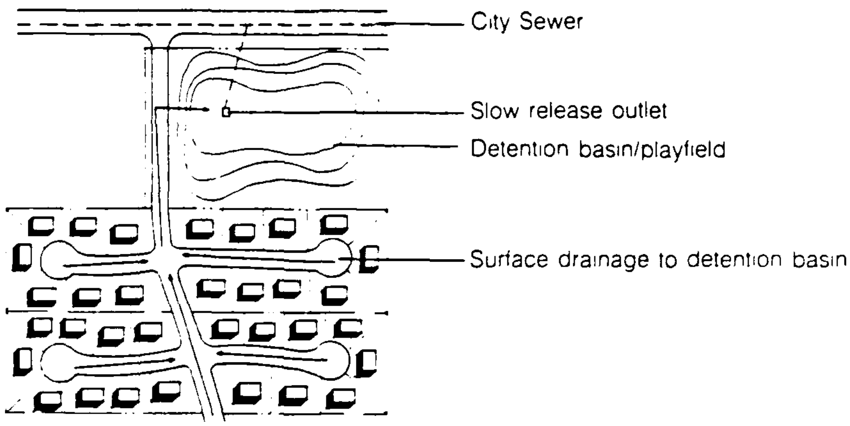


Figure 21. Alternative Layout For Storm Drainage System. (From Building Affordable Homes, HUD.)

curvilinear streets, more of the existing vegetation and drainage paths can be preserved. These existing features, plus slightly modified open channels, swales and site land grading, can also provide surface drainage and still provide usable green space for the development. It is noted that the use of grass swales can be applied in areas of moderate annual rainfall. Areas in tropical zones or with excessive annual rainfall will most probably require constructed surface swales and ditches or underground drainage culverts and pipes.

Curvilinear Storm Sewers. Similar to the use of curvilinear sanitary sewer lines, storm sewers can also parallel street patterns and thus reduce the number of storm manholes and catch basins.

Maximum Spacing Between Structures. To further reduce the number of storm sewer structures, such as manholes and catch basins, the spacing between the structures can be maximized to the extent of cleaning equipment.

Foundations

The foundation is the most variable component of the structural system of the house, depending on soil properties, topography, climate and building live and dead loads. Most of the innovations in residential foundations have centered on the design and construction of footings, foundation walls and slabs.

Table 3 summarizes the OVE research conducted by NAHB concerning the key design and construction techniques that can be used to lower construction costs. Amplifying remarks are provided for footings, foundation walls and slabs.

Footings

The major focus of OVE design footings is to reduce the size of footings by sizing the footing according to the actual soil bearing capacity. One and two story wood framed housing typically do not exceed 1500 lbs/lf and 2000 lbs/lf, respectively, while allowable soil bearing capacities in most areas range between 1,500 and 3,000 psf. Table 4 provides the OVE recommended footing design widths based on total building design load and allowable soil bearing capacity.

Foundation Walls

Foundation walls typically are made of concrete block or reinforced and non-reinforced concrete. In many cases, the thickness of the blocks and concrete, and the use of reinforcement far exceeds actual design requirements. The key design parameter for foundation walls is the height of backfill since it dictates the earth pressure acting against the foundation wall.

Table 3

Foundation Design and Construction

Component	OVE Technique(s)
Footings	1. Design footings to the actual soil bearing capacity and avoid costly overdesigned footings.
	2. Reduce thickness of concrete footing through proper reinforcement.
	3. Extend footings to or below the frost line and down to the original undisturbed soil.
	4. Use a monolithic concrete slab with no footing where basements are not required.
Foundation Walls	1. Design for the minimum thickness foundation wall based on the actual height of backfill.
	2. Where allowable, use pressure treated wood construction for basement walls.
Slabs	1. Reduce slab thickness to 2 1/2" over carefully prepared subbase.
	2. Eliminate WWF.
	3. Eliminate vapor barriers if moisture migration is not critical.
	4. Eliminate granular subbase if moisture problems do not exist and if no capillary break is required.
	5. Increase spacing of control joints to be more effective.

Table 3

(Continued)

Component	OVE Technique(s)
Slabs	6. Use crawl space construction to minimize foundation and slab work on sloping sites.
	7. Concrete slab foundations are the most cost effective foundation-floor combination since they are not subject to the span limitations of other types of foundations. A monolithic concrete slab, combining the floor and footings in a single pour, is the least costly of all foundation types if proper conditions exist.
	8. Insulate slab perimeters in cold climates to prevent excessive heat loss.

TABLE 4

FOUNDATION FOOTING DESIGN

Footing Width In Inches for Typical Loads

Total Design Load (lbs/lf footing)	Allowable Soil Bearing Capacity (psf)			
	1500	2000	2500	3000
1000	8	6	4.8	4
1500	12	9	7.2	6
2000	16	12	9.6	8
2500	20	15	12	10

(From *Home Building Cost Cuts*, HUD.)

Table 5 provides minimum foundation wall thicknesses for walls laterally supported and unsupported at the top.

A new development in foundation wall construction has been the use of pressure treated wood walls. The advantages include improved below grade living conditions, easy installation of electrical wiring, insulation and wall finish materials, suitability for construction in cold weather and potential for prefabrication (1).

Slabs

OVE studies have determined that in many cases, concrete slabs are overdesigned or that field construction practices do not take full advantage of the design factors contained in the plans and specifications. Primarily, excessive slab thickness and the use of granular subbase and welded wire fabric is often unnecessary.

If a slab subbase is properly prepared and uniformly compacted, a granular subbase can be eliminated if there is no moisture problem. In addition, a smooth well prepared subbase can also accomodate a slab of reduced thickness down to two and one half inches. The ability to achieve a suitable subbase is often more difficult, however, and may be more costly than the conventional three and one half to four inches thick concrete slab.

TABLE 5

MINIMUM FOUNDATION WALL THICKNESS WITH NORMAL SOIL CONDITIONS*

Type of Foundation Wall	Minimum Wall Thickness (inches)	Maximum Height of Finish Grade Above Basement Floor	
		Foundation Wall Laterally Unsupported At the Top (Feet - Inches)	Foundation Wall Laterally Supported At the Top (Feet - Inches)
Solid Concrete	6	2 - 6	5 - 0
	8	4 - 0	7 - 0
	10	4 - 6	7 - 6
	12	5 - 0	7 - 6
Concrete Block	6	2 - 0	2 - 0
	8	3 - 0	4 - 0
	10	4 - 0	6 - 0
	12	4 - 6	7 - 0

*Depending on local conditions, reinforcement may be required. Check with a local engineer.

(From <u>Building Affordable Homes</u>, HUD.)

The use of welded wire fabric (WWF) is probably one of the more abused practices in slab construction as its purpose is seldom understood. Since residential slabs are considered nonstructural, WWF is not used to prevent shrinkage cracking (the amount of steel is insufficient), but rather to contain these cracks. Shrinkage cracks are not of structural origin and should not be considered a problem. Many builders use WWF because they believe it provides an additional margin of safety against cracking. During the pouring of a concrete slab, however, the WWF is frequently stepped on, dislocated and not maintained in the upper portion of the slab where it is most effective. Hooking the mesh after the concrete is placed is an inadequate practice. Unless required by the jurisdiction or local codes, the use of WWF can be eliminated, and result in a substantial cost savings while not affecting the integrity and function of the concrete slab (4).

Floor Systems

Current floor system construction normally consists of concrete slabs or wood framed floors. The use of concrete slab floor construction was addressed in the previous section on foundations. This section on floor systems will, therefore, concentrate on wood frame construction and the recommended OVE design and construction techniques. It is noted that the discussion of wood frame construction techniques also applies to metal frame floor construction.

Table 6 lists the key OVE design and construction principles with remarks that apply to floor system construction. Figure 22 illustrates many of the techniques discussed in Table 6.

Wall Systems

Like wood and metal framed floor systems, wall system design and construction can also take advantage of OVE techniques. Most of these techniques consider the optimization of material usage and labor and are presented in Table 7. Figure 23 provides a comparison of the conventional and OVE construction techniques used in wall system construction.

Roof Systems

Probably the single most effective measure to take in optimizing time and cost in roof system installation is the use of prefabricated twenty-four inch on center roof trusses. This modular system coordinates easily with the previously described modular framing for floor and wall framing components and greatly reduces material waste, installation time and labor costs.

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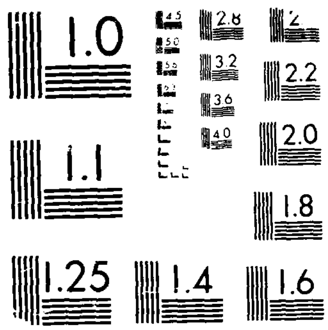

MICROCOPY RESOLUTION TEST CHART

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Table 6

Floor System Design and Construction

OVE Technique	Remarks
1. Use modular dimensions, most commonly 24" o.c. for floor joists	Simplifies layout and handling; can coordinate with 24" o.c. wall and roof framing.
2. Use built-up wood beams for center support	If required and if spans are less than 40 ft., use a built-up beam instead of a more expensive, more difficult to handle steel beam
3. Eliminate or reduce size of sill plate	Floor framing can be anchored directly onto the top of the foundation with anchor straps spaced 4-8 ft. If a sill plate is used, a 2x4 is adequate.
4. Use in line off-center spliced floor joists	Can increase allowable span of floor joists by maintaining continuity over center span with alternating splices at unequal lengths from the center support.
5. Eliminate double floor joists	Double floor joists are unnecessary under non-load bearing interior partitions.
6. Eliminate or reduce band joist	A band joist serves little or no structural function when wall studs are aligned directly over floor joists. If a band joist is necessary for framing layout, 1x lumber may be used instead of the typical 2x lumber.

Table 6

(Continued)

OVE Technique	Remarks
7. Eliminate bridging	The common practice of using bridging has been proven not to contribute to the strength of the floor system. For floor joists smaller than 2x12, most major codes no longer require bridging.
8. Use a glue-nailed, tongue-and-groove plywood subfloor	Glue-nailing plywood sheets over floor joists spaced 24" o.c. increases the allowable span of the floor, stiffens the floor system and eliminates squeaking.
9. Use sill anchors instead of anchor bolts	Strap anchors or powder-driven sill fasteners are normally faster to use than anchor bolts.
10. Use cantilevered floor joists to increase dimensions of above grade rooms	Two to four feet in housing width can be added without changing joist size by cantilevering joists over the building's foundation or basement wall or first floor load bearing wall line.
11. Use prefabricated floor trusses	Probably the most cost effective measure that incorporates many of the previous OVE techniques. Installation time and labor requirements are reduced, less material is used and larger span flexibility is possible.

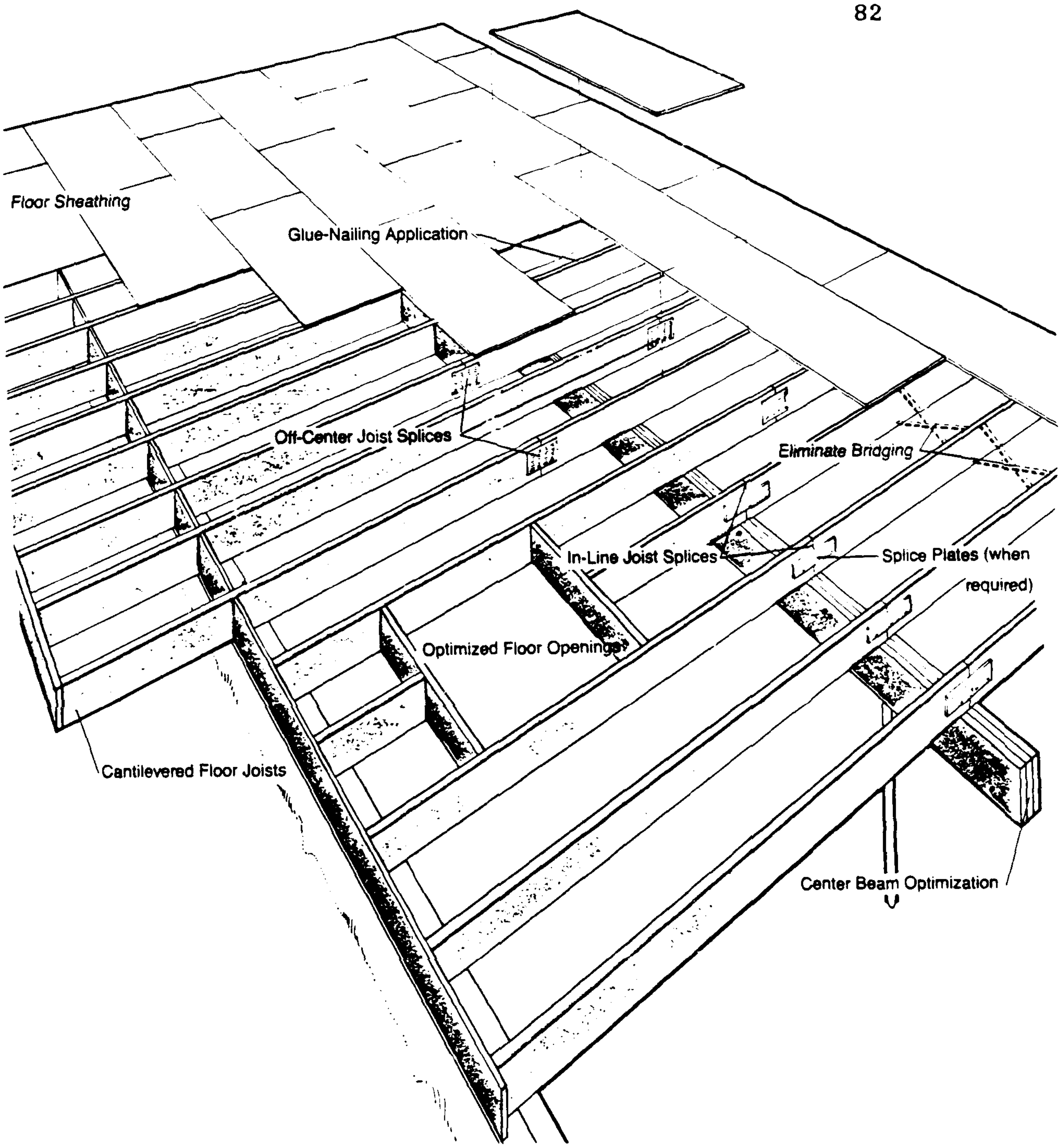


Figure 22. Floor System Design. (From Home Building Cost Cuts, HUD.)

Table 7

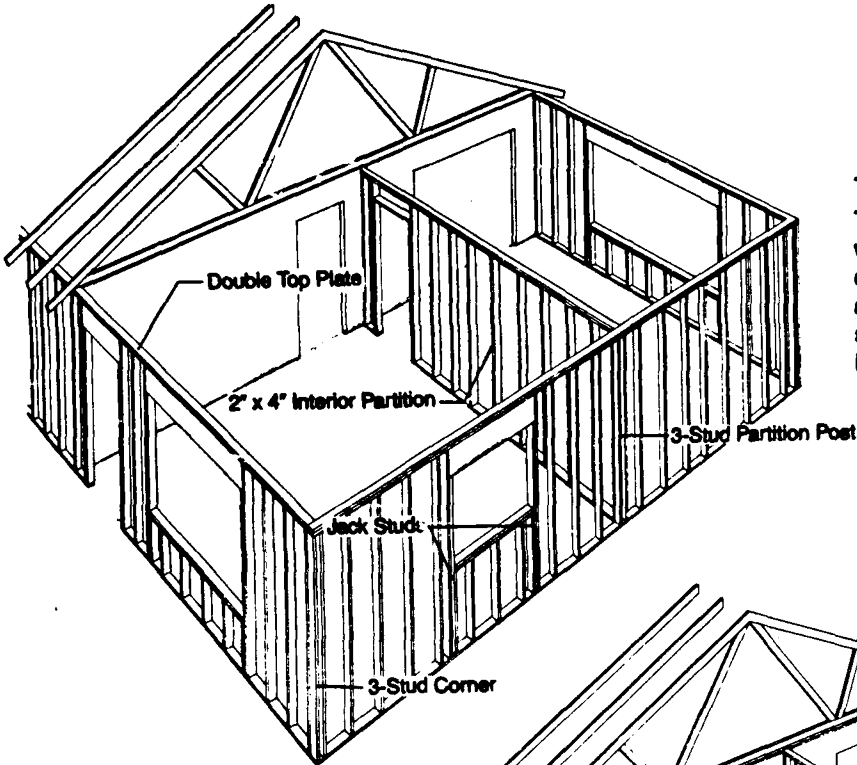
Wall System Design and Construction

	OVE Technique	Remarks
1.	Use 24" o.c. wall framing	Simplifies layout, reduces material waste and coordinates with floor joist and roof framing.
2.	Use a 7'-6" wall height	Allowed by most building codes, the 7'-6" wall instead of an 8'-0" wall reduces necessary amount of materials, reduces heat loss and gain with a reduced total wall area and increases the apparent size of interior rooms on the horizontal-vertical scale.
3.	Use a single top plate	A single top plate can be used on load bearing and non-load bearing walls with 24" o.c. framing since it serves no structural purpose.
4.	Use a 1x bottom plate	Like a top plate in 24" o.c. framing, a bottom plate serves no structural function and is not needed. It can be used, however, to simplify the layout and alignment of wall studs. In this case, a 1x bottom plate is sufficient.
5.	Use a two stud corner	The third stud in a three stud corner can be eliminated since its only purpose is to back up the interior finish. In its place, metal drywall clips or wood cleats can be substituted.

Table 7

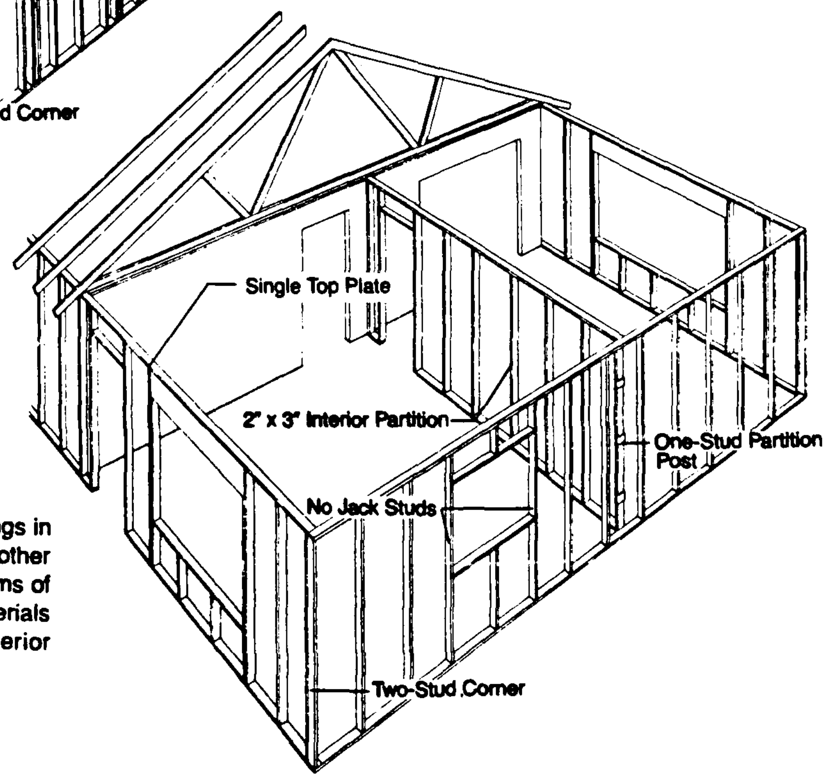
(Continued)

OVE Technique	Remarks
6. Eliminate partition posts	A partition post is not required where an interior partition intersects an exterior wall since its only purpose is to support the interior finish material. Instead of the post, metal drywall clips or wood cleats can be substituted for support.
7. Eliminate mid height blocking	Mid height blocking is not required for structural bracing or firestopping as standard framing members provide these necessary characteristics.
8. Use glue-nailed plywood headers	A glue-nailed plywood box header can be used as a less expensive alternative to a structural header.
9. Eliminate interior trim	Interior window trim can be eliminated by installing the interior drywall into the opening at the head and jambs.
10. Use prefabricated wall panels	The most cost effective alternative to framing on site is the use of prefabricated wall panels that reduce material waste, installation time and labor costs.



16" Framing

This traditional method is often employed with little understanding of the functional origins of individual framing members and details. In conjunction with "modern" sheathing and siding, it typically results in overstructuring and material waste.



24" Framing

Not only is there a substantial savings in the amount of lumber used, but other savings accrue to the builder in terms of reduced nailing of exterior materials (sheathing and siding) and interior finishes (gypsum drywall).

Figure 23. Conventional and Alternative Wall Framing Methods. (From _Home Building Cost Cuts_, HUD.)

Prefabricated roof trusses have become the most popular framing method due to excellent quality control at the manufacturing plants, flexibility and variety in truss types and sizes and the engineering support from truss manufacturers.

Although prefabricated roof trusses will probably achieve the greatest savings in the installation of a wood or metal roof system, there are several additional measures that will also reduce construction costs. These methods are outlined in Table 8.

Support Systems

The support systems in a residential unit include the plumbing, electrical and HVAC systems. HUD and NAHB research has concentrated on developing several innovative techniques in each of these areas. These techniques have considered the modular framing guidelines described in floor, wall and roof construction and have resulted in proven ways to reduce unit construction costs (5). Table 9 describes these design and construction techniques and amplifying comments are provided as follows.

Plumbing

A major milestone in the recognition and acceptance of modified plumbing design standards occured in September 1985 when the Council of American Building

Table 8

Roof System Design and Construction

	OVE Technique	Remarks
1.	Prefabricated roof trusses	Coordinate with framing of wall and floor systems and greatly reduces material and labor costs and installation time.
2.	Eliminate rake overhang on a gable roof	The rake overhang is a costly detail in terms of material and installation cost and serves no real purpose other than appearance. In many cases, it can also be a maintenance problem.
3.	Eliminate roof overhang	Roof overhang and soffit construction can be eliminated, providing that a gutter is installed to prevent water infiltration through the roof sheathing and exterior wall joint.
4.	Use gable end vents instead of other types of vents	Gable end vents constructed of a simple rectangular aluminum or plastic vent are a less costly alternative to attic ventilation.

Table 9

Support System Design and Construction

System	OVE Technique(s)
Plumbing	1. Downsize sanitary waste drains and vents.
	2. Optimize arrangement of fixture group layouts.
	3. Stack fixture groups for more than one floor.
	4. Minimize service and drainage runs.
	5. Use chlorinated polyvinyl chloride (CPVC) or polybutylene (PB) for distribution piping.
	6. Use PVC for DWV piping.
	7. Use prefabricated utility cores.
Electrical	1. Eliminate circuits, receptacles and switches where not really needed.
	2. Use 15-amp circuits.
	3. Eliminate door chimes.
	4. Eliminate unnecessary light fixtures.
	5. Locate heavy loads close to load center.
	6. Use plastic instead of metal utility boxes.
	7. Consider a Smart House electrical system.
HVAC	1. Perform accurate heat loss calculations and size equipment accordingly.
	2. Downsize duct systems.

Table 9

(Continued)

System	OVE Technique(s)
HVAC	3. Use radial duct systems.
	4. Use electric baseboard heating in units where air conditioning is not required.
	5. Exhaust bath fans directly into well ventilated attics.
	6. Install an effective attic ventilation system.

when the Council of American Building Officials (CABO) unanimously adopted residential plumbing guidelines developed by the NAHB Research Foundation. These guidelines primarily included the downsizing of sanitary waste and vent lines, thereby reducing material and construction costs. Extensive testing by NAHB and the Stevens Institute of Technology supported the modifications and proved that adequate drainage and venting in a residence was still achieved (19).

Another very effective plumbing innovation is the use of clustered plumbing fixture groups. This involves the arrangement of typical plumbing groups such as baths, kitchen and laundry back-to-back on a common wall, or between multiple stories on a vertical common plumbing stack. This minimizes the amount of service, distribution and drain-waste-vent (DWV) piping required and centralizes the plumbing work in one major location. Figure 24 illustrates a typical distribution schematic using this concept.

Although copper is still the most widely used material for hot and cold water supply (4), the use of plastic piping has increased greatly and is used extensively within the prefabricated housing industry. Plastic piping is used in distribution and DWV piping arrangements and is normally less expensive, lightweight

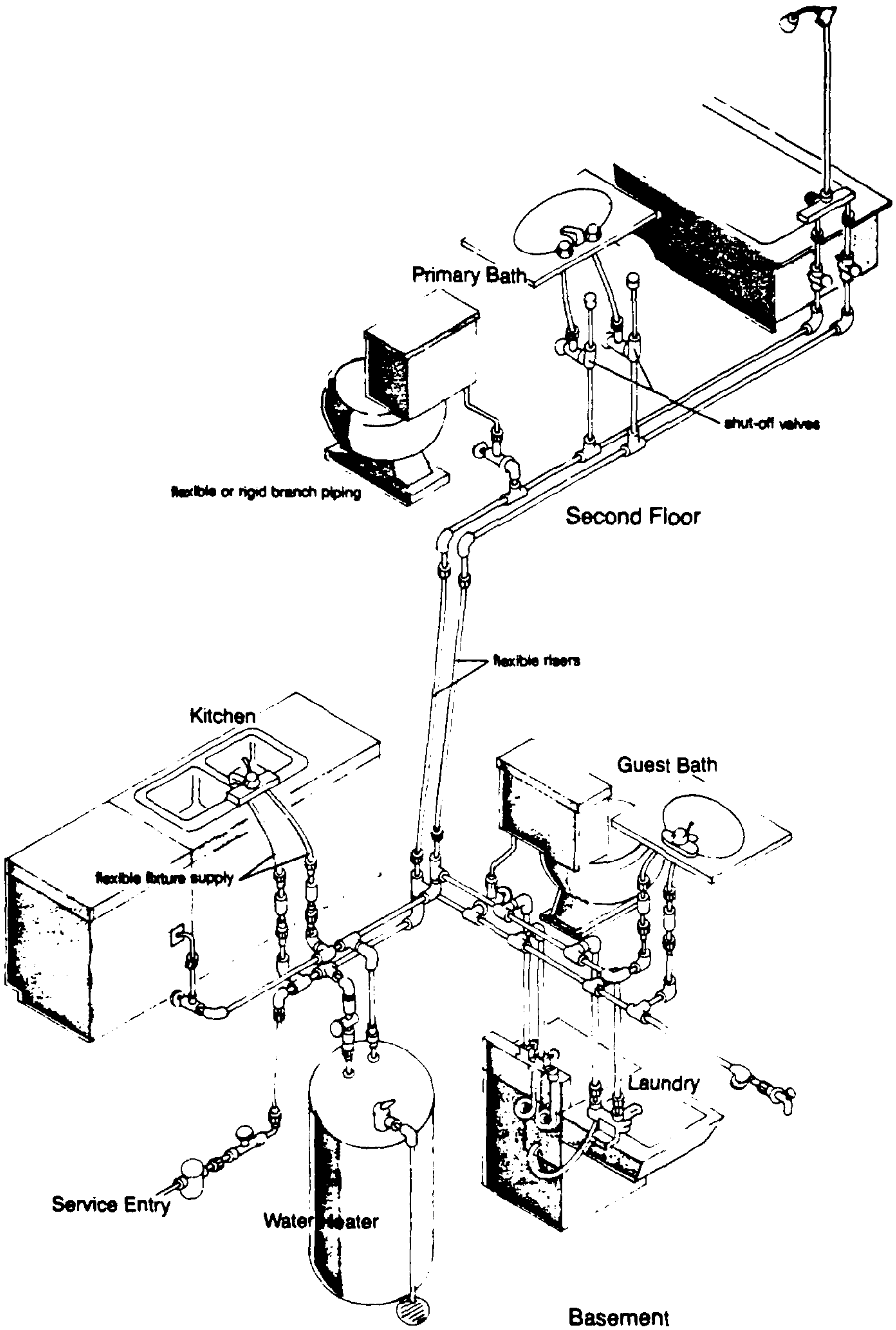


Figure 24. Clustered Plumbing Arrangement. (From Home Building Cost Cuts, HUD.)

and easier to install. Table 9 lists the types of piping materials that can be used in each arrangement.

In addition to the use of plastic piping materials by the prefabricated housing industry, the industry has also developed and successfully used prefabricated utility cores. These cores are frequently the kitchen component, framed and rough finished, with all plumbing arrangements installed in either of the four walls of the core. When the core is installed as framing proceeds, plumbing for adjacent bathrooms and laundry is easily connected to the runs installed in the utility core walls.

Electrical

Currently Used Techniques. Most of the OVE techniques developed for the electrical system involve the elimination of unnecessary circuits, switches, receptacles and light fixtures. These recommendations should not be interpreted to indicate that flexibility and convenience in the unit should be eliminated or greatly reduced. There is frequently an opportunity, however, to reduce the number of circuits, switches, receptacles and light fixtures that are actually redundant and unnecessary.

Eliminating a single circuit will save over $25 in home run and circuit breaker costs and eliminating a receptacle can save $15-$20 for each location. In each housing unit, there are several major appliances that require 240-V circuits, such as the electric clothes dryer, range, hot water heater and electric furnace. These circuits require the use of heavy wiring, yet if these appliances could be clustered as close to the load center as possible, then approximately $100-$150 can be saved in wiring costs (3).

A common material development in electrical system installation has been the use of plastic utility boxes instead of metal boxes. Plastic boxes are less expensive, lightweight for shipping, require no grounding connectors, have installation nails preset and require less installation time.

The Smart House. The Smart House is an electrical design that incorporates a single cable wiring system with a central control panel. It performs energy distribution, communications and controlling in a residence and provides exceptional ease and flexibility in design, construction and usage (20).

One electrical cable in a house will handle power distribution, control/data distribution and audio/video signal distribution in a closed loop, programmed power system. Basically, the system operates as follows:

1. A device (hair dryer, power drill, clothes dryer, etc.) is plugged into a special electrical outlet.

2. A signal from the device is sent to the control center which identifies the power required for operation of the device.

3. The control center supplies the required power to the device.

4. As the device is used, its performance is monitored by the control center.

5. If faulty operation occurs, the control center interrupts the power supply, preventing potential shock and fire hazards.

6. The control center operates off of 240-V power supplied to a residence and also has a backup power capability in case of an electrical service interruption.

The Smart House concept was developed in the mid-1980's by NAHB and thirty-eight manufacturers and organizations under the organizational title of the Smart House Development Venture, Inc. Commercial availability in production housing is anticipated in 1988 or 1989 and the Smart House concept will be formally considered by the National Electrical Code (NEC) Committee for the 1987 Code revision (20). Although the Smart House system is not in current use, its potential appears to be unlimited in terms of revolutionizing home electrical design and construction.

HVAC

The key factor to consider in HVAC design is the selection of the most economical system for the unit and local climate. Types and costs of available fuel, maintenance characteristics and environmental factors can greatly influence the type of system to be installed, whether it be central air conditioning and heating, electric or oil heating or no system at all, other than ventilation.

With well constructed and insulated homes, heating and cooling equipment can sometimes be downsized since typical heat or infiltration losses can be reduced. Accurate heat loss calculations for each room in a house can determine what size of system will be sufficient for adequate heating or cooling.

Similar to reducing plumbing and electrical system runs through clustering, duct runs can be reduced with a radial duct system that is located directly over the HVAC equipment center.

A very cost effective design concern for a house located in any climate is the ventilation system. A well designed ventilation system depends on proper vent sizing and location and the maximum use of natural forces that cause air to move, such as convection and differential air pressure (4).

Soffit vents, gable end vents, roof vents, and continuous ridge vents are some of the common and effective ventilation types that should be used in combination with each other for maximum effect.

The importance of a well designed ventilation system has advantages in the winter and summer. In the winter, condensation on the underside of roof sheathing or on attic insulation can cause material damage and ice damming on the roof where eaves are used. With adequate attic ventilation, warm air that enters the attic space from the adjacent ceiling can be quickly exhausted and thus not condense. In the summer, high temperatures create extremely hot air in attics, which can be transferred to living areas below by radiation and conduction. Attic ventilation will exhaust this hot air, reduce heat transfer and reduce the load placed on the air conditioning system to provide a comfortable environment in the living areas (4).

Building Materials

There have been many material developments in residential construction that have resulted in lower material and shipping costs and reduced handling and installation time. Some of these developments have been previously mentioned in the support systems section of this chapter. Some of the proven cost effective materials which are commonly used today are listed in Table 10.

Summary

This chapter has presented and discussed Optimum Value Engineering (OVE) and other innovative design and

Table 10

Building Materials

1. Structural particleboard instead of plywood sheathing.
2. Flexible HVAC duct instead of metal duct.
3. Plastic piping instead of metal piping in plumbing systems.
4. Plastic utility boxes instead of metal boxes.
5. Direct burial electrical cable.
6. PVC water and sewer line piping.

construction techniques that can be used in residential construction. These techniques were categorized into eight subdivisions as defined by the NAHB Reserach Foundation in their OVE studies.

Of these eight subdivisions, Site Design and Development and Site Utilities and Storm Drainage were emphasized since these topics represent the greatest cost savings potential. The remaining six subdivisions considered the design and construction of the housing unit and were presented in a summary manner.

The next chapter, Navy Family Housing Case Study, will examine the application of OVE design and construction techniques on a current Navy multifamily housing project. The case study will attempt to determine if the techniques outlined in Chapter Three are currently being used or can possibly be used in a Navy family housing contract.

CHAPTER FOUR

NAVY FAMILY HOUSING CASE STUDY

This chapter examines a Navy family housing project that was used as a case study to investigate the current use of Optimum Value Engineering and other innovative design and construction techniques. Much of the discussion concerns a study of the project plans and specifications and interviews conducted with on site construction management personnel. From this case study, it will be determined if OVE techniques are typically used or could be used by residential contractors that are awarded contracts for Navy family housing.

Project Description

The project selected as the case study was Contract N62740-85-C-0054, Woodbridge Crossing, A 300 Unit Apartment Project, located in Newport News, Virginia. The contract was administered by the Atlantic Division of the Naval Facilities Engineering Command (LANTDIV) which is headquartered on the U.S. Naval Base in Norfolk, Virginia.

One unique feature of this contract is that it is administered under the U.S. Navy's Section 801 Family Housing Program, which allows for leased housing from the public sector for a maximum period of twenty years.

Although this is unlike most Navy family housing projects in which the Navy becomes the permanent owner, it was awarded and administered in accordance with the standard Request For Proposal (RFP). It can be used, therefore, as a feasible case study.

The contract was awarded to the Hunt Building Corporation of El Paso, Texas in September 1986 at a cost of $24,999,300. Hunt Building Corporation has completed many military family housing projects, including two recent projects for the Navy in Patuxent River, Maryland (1986) and San Diego, California (1984). Hunt is, therefore, considered to be a valuable source of information about Navy family housing because of their past experience and success. Completion and beneficial occupancy of the 300 unit project occurred in November 1987.

The project scope involved the design and construction of 300 units of multifamily housing with site improvements and support systems on a twenty-four acre site located near Interstate-64 and Jefferson Avenue in Newport News, Virginia. See Figure 25. Site work included water, sanitary sewer, electrical and storm drainage systems, site roads, parking lots and walkways, recreational facilities, auxiliary support buildings and landscaping. The 300 units of family housing are to be used by Navy enlisted personnel

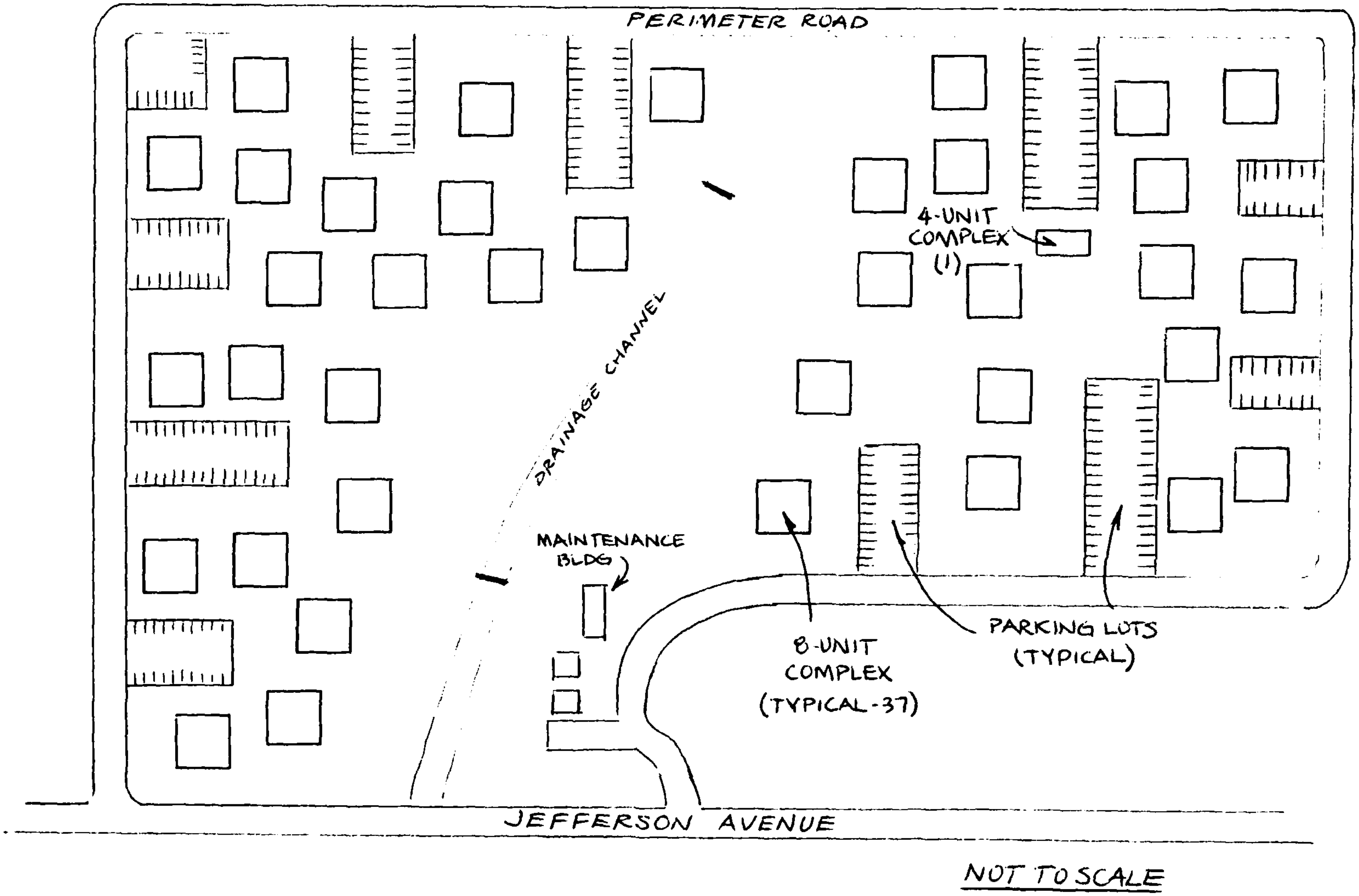


Figure 25. Project Sketch - Woodbridge Crossing, A 300

Unit Apartment Project, Newport News, VA stationed in the Norfolk-Portsmouth-Yorktown, Virginia area. The 300 units are divided into the following categories:

No. Bedrooms	No. Bathrooms	Total No.
2	1 1/2	150
2	2	75
2	2 1/2	75

As a turnkey contract, the contractor completed his own design under the guidelines of the RFP and constructed the project in accordance with his accepted design and the contract documents. The proposal of the Hunt Building Corporation was evaluated to have the lowest dollar to quality point ratio.

Site Visit Findings

A meeting with the Family Housing Department of LANTDIV and a visit to the project site was conducted by the author on 20 August 1987. Information concerning current use of the Navy family housing RFP and possible use of Optimum Value Engineering techniques was obtained from both Government and Contractor representatives during the visit. Appendix C contains the agenda used by the author during the site visit.

Results of Discussions With the LANTDIV Family Housing Department

Project Administration. The Director of Construction Projects at the Family Housing Department has overall responsibility for the administration of the contract. Because the contract was under the guidance of the Section 801 Program, there was no direct Government adminstrator, such as a ROICC (who is assigned to most housing projects) associated with the project. Instead, the construction process was monitored and inspected by Newport News building officials in accordance with The BOCA Basic National Building Code (Building Officials & Code Administrators) (21). While this form of inspection was considered adequate, the arrangement did not completely satisfy the Navy's interest in ensuring that the project was built per the plans and specifications approved by the Navy.

Site Design and Development. The major guidelines to be followed in the RFP for site layout are those mandating a maximum unit density per acre and minimum unit setbacks. If these guidelines are satisfied, then a contractor has the flexibility to arrange the units in a manner that he deems most effective. The clustering of multifamily units is common on many Navy family housing projects and generally provides an attractive and common sense approach to site development. The use of solar and wind orientation, however, would be difficult to enforce in design criteria and would probably result in an unattractive development if enforced.

Probably the most important, yet sometimes least regarded, point to consider in site development is environmental enhancement. Despite the additional costs to a contractor in site clearing and unit construction, it is beneficial to the Navy to have as many trees retained on site as possible. This improves the appearance of the site, trees serve as windbreaks in the winter and provide shade in the summer and add to the quality of life in military family housing. In this project, several trees on the interior of the site were retained, and where located in fill areas, tree wells were installed.

Site Utilities and Storm Drainage. Unless mandated by a local jurisdiction, the RFP usually provides the option of either an overhead or underground site electrical system. On this project, an underground system was installed and was essential in maintaining an open atmosphere within a very compact development. Overall, initial construction costs may be higher compared to an overhead system, yet the maintenance costs over the life of the development are normally greatly reduced.

As with most Navy family housing projects, only one or two electrical and water master meters are required for the site. This results in a significant savings over installing a meter for each unit. The joint trenching of water and sanitary sewer lines is not recommended or practiced by any of the Navy Public Works Centers or Departments and should be avoided. The current storm water management philosophy of retention and slow release is very reasonable and can be used on certain sites to add aesthetic value.

Unit Design and Construction. The RFP, in most cases, provides enough design flexibility so that a satisfactory variety of design proposals are usually submitted for the housing units. This supports the opinions obtained during the site visit that most of the current criteria and guidelines concerning unit design and construction are sufficient and do not require modification.

Unit Maintenance. Second to obtaining quality housing at an affordable cost, built per the plans, specifications and other contract documents, the Navy's major concern with family housing is maintenance. Consideration of some of the more controversial OVE techniques in light of these maintenance concerns, are discussed in greater detail in Chapter Five where specific OVE ideas are considered for inclusion in the current Request For Proposal.

<u>Observed Applications of OVE Techniques</u>

Review of the project documents and the site visit revealed that several design and construction techniques that mirrored Optimum Value Engineering concepts had been used by the contractor. It appears that even though the contractor was not familiar with the concept of OVE, he was aware of the various methods that could be used to simplify site and unit construction and hence reduce construction costs. Those applications of OVE techniques directly observed at the project site are presented in Table 11.

<u>Results of Discussions With the Contractor</u>

Using the agenda provided in Appendix C, the author and three contractor representatives discussed the concept of OVE and whether it could be used more extensively on Navy family housing projects. The contractor representatives interviewed were the project design engineer, project superintendent, and project maintenance foreman (to be responsible for maintenance of the hou ng during the Navy's lease period). Their comments, based on experience in both the military and commercial housing markets, concerning the use of OVE techniques are provided as follows.

Table 11

Observed Applications of OVE Techniques

Technique	Remarks
A. Site Design & Development	
1. Clustering of units	1. Each building consists of eight units clustered around separate parking lots.
2. Environmental enhancement	2. Perimeter trees and several trees on the interior of the site were saved. If more had been saved the site appearance would have been significantly improved.
3. Reduced pavement widths	3. Only one major 24 ft. road was constructed to service the individual parking lots. It was considered sufficient for all emergency vehicles and moving vans.
4. Rolled curbs	4. Rolled concrete curbs and gutters were installed along the perimeter road.
B. Site Utilities & Storm Drainage	
1. Common trenching of electrical, telephone, CATV and gas lines	1. Electrical, telephone and CATV lines were installed in the same trenches around the site.
2. Direct burial cable	2. Used extensively on this project and very common in construction.

Table 11

(Continued)

Technique	Remarks
3. Retention ponds	3. While a new retention pond was not constructed for the storm drainage system on site, an existing drainage channel was used to collect and safely transport site run-off to a nearby reservoir.
C. Foundations - Slabs	
1. Use of post-tensioned concrete in 4 1/2 in. concrete slabs	1. Although not a specific OVE technique, the use of post-tensioned concrete instead of WWF for all slabs was considered innovative and of sound engineering judgment due to the poor soil conditions at the site.
D. Floor Systems - Wall Systems - Roof Systems	
1. Glue-nailed subfloors	1. The 5/8 in. plywood subfloors were glue-nailed to the second floor joists to improve structural integrity and reduce squeaking.
2. Use of built-up wood beams for center support	2. Built-up wood beams were constructed for for center support of the second floor in all units.

Table 11

(Continued)

Technique	Remarks
E. Support Systems	
1. Use of 15-A circuits	1. 15-A circuit breakers were used for lighting circuits as permitted by the BOCA Code.
2. Ventilation	2. Gable end vents were installed for effective attic ventilation.
3. Heat pump recovery system	3. Heat pumps were installed for each unit.
F. Building Materials	
1. Flexible HVAC duct	1. Used solely for HVAC system.
2. Track vinyl siding	2. Metal nailing tracks and 3-strip vinyl boards were used to quickly and efficiently install the siding on the unit exteriors.
3. Interior storm windows	3. Guaranteed to provide the same insulation value as windows with exterior storm windows, these combinations greatly facilitated easy cleaning and replacement.

Site Design and Development. Zero lot line development has become very popular in residential housing, especially for single and duplex units. This is particularly true in California. As observed by the Hunt Building Corporation in many locations across the country, the objective today is to market a larger house with upgraded amenities and a smaller lot. This trend has been noted by many other developers and builders in the United States as well.

The specific use of solar and wind orientation for large residential developments, such as Navy housing projects which typically include 100 to 400 units, does not appear to be feasible. With the large number of units, several units will naturally take advantage of the solar and wind benefits, while many will not due to their somewhat random location on the site. In order to provide an attractive appearance and avoid repetitive rows of houses, not all units can ideally lie on an E-W longitudinal axis.

While project design criteria normally requires curb and gutters on all roads, the use of rolled curbs is certainly easier to install and less costly. Reduced widths of roads is also common, with a width of twenty-four feet generally accepted as being sufficient for roads within a development.

<u>Site Utilities and Storm Drainage.</u> According to the contractor personnel, the concept of joint trenching of water and sanitary sewer lines is not acceptable or regarded as a safe construction technique. Their opinion was based on past experience with the installation of water and sewer lines. In this project, the water and sanitary sewer lines were installed in separate trenches on opposite sides of the perimeter road.

Cleanouts in lieu of manholes were used in several locations on the site. In addition, manholes were spaced at a maximum distance of 400 feet around the perimeter road. With a rectangular perimeter road around the site, cost efficient manhole installation was obviously obtained due to the straightline sewer runs. The contractor was not familiar with curvilinear sewers.

In storm water management, the use of retention ponds is regarded as a good alternative to a complete underground drainage system and can normally add aesthetic value to a site. In this project, an existing drainage channel was retained and improved to collect and transport the site runoff to a nearby reservoir. The contractor was also not familiar with curvilinear storm sewers.

<u>Foundations.</u> The building foundations on this project were concrete slabs on grade with post-tensioned

reinforcement. Due to large fill areas at several locations on the site and the low bearing capacity of the existing soil, the contractor determined that slab cracking would create significant problems. Post-tensioned rods were, therefore, installed in the four inch thick slabs to ensure that the slab acted as an integral unit in the case of settlement or upheaval.

The contractor had worked with treated wood foundation walls on several commercial projects and found them to be effective and easy to install. Preference for treated wood or concrete among builders is usually based on past experience and habit.

Floor, Wall and Roof Systems. Although prefabricated floor trusses and wall panels are common in residential construction, this project was essentially stick-built. Only prefabricated roof trusses were used. Member spacing in the walls was sixteen in. o.c.

The contractor had strong negative feelings about twenty-four in. o.c. wall framing since his experience indicated that the sheathing tended to snake due to bows in the studs. In such cases, the rough finished wall had visible defects in it. He felt that the use of sixteen inch o.c. framing could, however, conceal any bows in the studs and not telegraph the defects through a finished wall.

Except for two stud corners, the contractor had not encountered the "reduction of framing components" concept of OVE. The contractor's experience with two stud corners has indicated that the necessary use of metal drywall clips was burdensome and ineffective. The contractor was not too receptive to the idea of eliminating the second top plate, bottom plate, band joist and partition posts since it was not a part of their standard practice.

All interior and exterior finish materials for the walls were five-eighths inch Type "X" gypsum wallboard. The contractor stated that the use of one type of gypsum wallboard, in this case the one hour fire resistant type (it was required for some walls in each unit) made it easier to manage and install the walls. In addition, using moisture resistant gypsum wallboard as an exterior sheathing for the vinyl siding proved to be less expensive than one half inch plywood.

Support Systems. The use of back-to-back plumbing arrangements in a common wall is common in residential construction but was not, however, used on this project. The contractor stated that this may have resulted in more work and higher costs for the plumbing contractor, yet it did provide better access for the owner in the case of maintenance, modification or expansion. Since the units were framed on site, a prefabricated utility core was not used.

In accordance with the governing BOCA Code, the contractor did install 15-A circuit breakers for lighting circuits in all units. This resulted in a reasonable cost savings since four breakers were used per unit. Substituting 1200 15-A circuit breakers for 20-A circuit breakers resulted in an approximate savings of $ 6,000 (22).

Building Materials. The use of structural particleboard was considered ineffective due to problems that occur when this type of sheathing becomes wet and expands. Plywood, although not used on this project, was regarded as the best exterior sheathing material, despite its higher cost. In lieu of plywood, moisture resistant exterior gypsum wallboard can be used to provide a suitable surface for the installation of the track vinyl siding.

Flexible duct for the HVAC system is used almost exclusively in residential construction because it is easier to install and less expensive than metal ductwork. In most cases, a single fiberglass plenum is attached to the air handling unit and flexible ducts radiate from the plenum to the various air diffusers.

Summary

This chapter has used a case study of a recently completed Navy family housing contract to investigate the current use and attitudes towards Optimum Value Engineering in the residential construction industry. Interviews with personnel associated with a construction firm that has completed many Navy family housing projects provided valuable information concerning OVE and other innovative design and construction techniques.

Discussions with a Navy Family Housing official also provided current thinking about the Navy's Request For Proposal and the design and construction criteria outlined in Section 2 of the RFP. Chapter Five will consider this information in determining what innovative design and construction techniques can and should be written into the current RFP to possibly improve the affordability of family housing for the U.S. Navy.

CHAPTER FIVE

APPLICATION OF OVE TECHNIQUES TO THE RFP

The previous chapters have addressed the U.S. Navy's housing construction contract Request For Proposal and the Optimum Value Engineering design and construction techniques. As introduced in Chapter One, the intent of this report is to define the interface between the RFP and OVE which was illustrated in Figure 2. This interface is not easily defined since any recommended modifications to the RFP must consider the environment and peculiarities of the Navy's contracting system.

This chapter will examine Section 2 - (entitled Design and Construction) of the RFP which contains the applicable design and construction requirements and guidelines. The ideas and techniques outlined in Chapter Three will be evaluated in terms of each applicable paragraph of Section 2 in order to identify possible modifications. For each evaluation, discussion will be provided to support or reject the use of the OVE technique. This discussion will use the information obtained from the case study described in Chapter Four and the author's personal experience.

The order of presentation in this chapter parallels that found in Chapter Three. Within each of the eight subdivisions of OVE, each item mentioned in Chapter

Three will be summarized based upon the information from the housing case study and other projects studied by the author. The current wording of the specific RFP paragraph will be referenced in Appendices D, E and F and discussion and recommended modifications will follow.

It should be noted again that the two major OVE divisions discussed in this paper, Site Design and Development and Site Utilities and Storm Drainage, will be examined in greater detail than the six remaining subdivisions dealing with the design and construction of the dwelling unit.

Site Design And Development

Unit Arrangement

Clustering and Solar and Wind Orientation of Units. The clustering of multifamily units is a very practical idea and one that can be used more extensively on Navy family housing projects. While the Newport News project used clustered townhouse arrangements, many projects use duplex, fourplex and sixplex buildings, but do not take advantage of clustering. The design of the projects at Subic Bay, RP and Colts Neck, NJ used these types of buildings, but situated them along lengthy curvilinear streets (18,22).

Clustered arrangements could have reduced development and road costs and provided more usable green space.

The following example utilizing the information provided in Figure 5 illustrates the possible savings that can occur between the two design approaches. One of the improvements in the clustered townhouse site plan (Fig. 5(b)) included reduced road length, clustered units with more usable green space and a more attractive setting. The same number of units with the same unit density per acre was maintained, yet a more attractive arrangement was obtained.

In regard to development costs, consider only the savings generated by the reduction of road length by 463 feet. Assuming a two inch thick asphalt pavement in the development, a twenty-four foot road width and a unit cost of $10/sy for subbase, binder and wearing courses (22), the costs for roadwork in each development are as follows:

Arrangement	Road Length	Asphalt	Cost
Conventional (Fig. 5(a))	2700 ft	7200 sy	$72,000
Clustered (Fig. 5(b))	2237 ft	5965 sy	$59,650
Savings			$12,350

It should be noted that the cost savings occured on a development of only eighty-two units. The savings would be much more significant for a large Navy family housing project of 200-500 units. In addition, reduced costs would also be obtained due to reduced site clearing and landscaping requirements.

Although strict attention to solar and wind orientation may be difficult to mandate, it should be examined by a designer in order to take advantage of natural characteristics. Very often, the proper orientation of one street or a group of streets could greatly enhance the natural lighting, heating and cooling in a number of units.

In the RFP, Paragraph 2B.1b, Building Arrangements, outlines the criteria to be used for street layout and building arrangements (see Appendix D). This paragraph adequately outlines certain desired features and even hints at some of the innovative techniques previously discussed. In order to strengthen these ideas and add additional guidelines, the following revisions, with modifications highlighted, are recommended:

> 2B.1b Building Arrangements: Building arrangements should be informal and imaginative with setbacks and orientation to provide for the best view, privacy and variety. Variety in groupings, arrangements, and siting configurations of buildings is encouraged to fit varying conditions and to provide attractive residential patterns and streetscapes. The use of building clusters and more usable green area is encouraged. Rigid, gridiron-like street and building layouts are undesirable, a system of curvilinear streets and cul-de-sacs or parking areas is preferred. Planning shall take into consideration natural characteristics of the environs and climatic

> conditions. *Attention to solar and wind orientation is required so as to take advantage of these natural conditions.* Design should capitalize upon economies inherent in the natural characteristics of the site, reducing street frontage, and consolidating utilities and common open spaces. The proper grouping of units will provide backyard screening, separation of pedestrian and vehicular traffic, recreation and natural open spaces. Clearance between adjacent buildings shall consider requirements for fire protection, safety, convenience of pedestrians, privacy and emergency access. Proposers are encouraged to consider energy conservation when developing their proposed building arrangements. Appropriate buffer areas suitable for landscaping shall be provided to separate and screen from undesirable external influences. (6) [Italics added]

Reduced Lot Sizes and Setbacks. Although zero lot line development is another very effective idea, its use seems best suited for single or duplex units. Since most Navy family housing arrangements are typically more than two units per building, this requirement may not be feasible. In the RFP, Paragraph 2B.1d, Building Setbacks, contains the minimum setbacks for a building with respect to adjacent buildings, streets and site boundaries. Since these distances are based on Navy Design Manual requirements (24), a maximum unit density per acre figure, and appear to be practical, they should not be altered.

Environmental Enhancement. Review of the Newport News project and several other Navy family housing projects reveals that one of the most common shortcomings of site design has been the removal of existing trees. In addition to providing natural views and setting, this one feature has a great impact on the overall appeal of the site. As discussed under solar and wind orientation in Chapter Three, trees also have energy related assets during the summer and winter.

Although it may be difficult to enforce the retention of all existing trees on a site, there are several guidelines that can be followed to improve the development. In general, the retention of existing trees will depend on the cut and fill areas, and the location of roads, utilities, buildings and other support facilities such as recreational courts and maintenance buildings. Assuming that there is still a reasonable number and variety of trees available after these facilities are located, stronger language in the RFP could mandate the preservation of the existing trees.

Paragraph 2.B10, Landscaping, subparagraph (c), Existing Trees, generally states that any existing trees shall be saved and protected on site, if possible (see Appendix D). Realizing the benefits of trees on the site and around buildings, the following modification is recommended:

> 2.B.10 c. Existing Trees: *All existing trees that do not interfere with road and utility installation and that are no closer than 15 feet to any wall of a building or recreational court footprint shall be saved and protected during the construction phase.* (6) [Italics added]

If applicable, a minimum tree diameter can be inserted into the above paragraph and if trees are highly desired, tree wells for groups of trees can be mandated in shallow fill areas of two to five feet. The reviewing authority of the RFP should use sound judgment in determining whether the retention of trees is feasible and cost effective before including a requirement for tree wells.

Street Layout

Curvilinear Streets. A discussion of curvilinear streets was included in the section on Unit Arrangement.

Reduced Pavement Widths. Paragraph 2B.2b, Street Width Criteria, of the RFP contains street width criteria that would be considered excessive by OVE standards (see Appendix D). It is important to note that the RFP criteria differentiates between units located on zero, one or two sides of the street, whereas the OVE guidelines consider the function of the street and the anticipated parking requirements.

Review of the Newport News project indicates that a twenty-four foot wide street was used as a perimeter road, with parking lots located on the interior side of the road. These parking lots could not, however, accomodate large moving vans and other emergency vehicles with parked cars in the lot. It was, therefore, probably assumed that the perimeter road would serve this purpose.

With regard to the street width issue, a simple cost comparison for a 2000 ft. section of roadway can illustrate the potential cost savings due to reduced road widths. Assuming a two inch thick asphalt pavement and a unit cost of $10/sy for subbase, binder and wearing courses (22), the following costs can be considered:

Road Width (ft)	Asphalt (sy)	Cost ($)
36	8000	80,000
34	7555	75,500
30	6667	66,670
28	6222	62,220
24	5333	53,330

As is evident, the selection of a twenty-four foot road width instead of a twenty-eight foot road width can result in an approximate savings of $8,890 for every 2000 ft. of roadway. Greater savings are possible when selecting between the twenty-four foot road width and a thirty, thrity-four or thirty-six foot road width.

If this design feature was considered adequate on this project, and if the OVE recommended street widths are considered practical, then the current RFP requirements can be modified. The following paragraph which is partially based on the guidelines contained in Table 2 is, therefore, recommended as a substitution :

2B.2 b. Street Width Criteria:

MINIMUM STREET WIDTH (FEET)

Type of Street	No Units Sited on Street	Units Sited One Side	Units Sited Both Sides
Main Collector Streets	24	36	36
Secondary Streets	24	28	36

Minimum street width is from back of curb to back of curb. (6) [Italics added]

Reduction or Elimination of Curbs, Gutters and Sidewalks. Curbs, gutters and sidewalks have typically been considered as necessities on a site. Current criteria mandates curbs and gutters on both sides of any street, yet states that sidewalks are simply "desirable" (see Appendix D).

On roads of high traffic volume, such as arterial, collector and some secondary roads, concrete curbs and gutters are necessary and should always be installed. Some secondary roads, however, such as dead ends, cul-de-sacs, lanes and places do not really require curbs and gutters. In their place a well graded and established grass swale would be adequate for normal rainfall. It is noted that in areas of excessive annual rainfall, concrete curbs and gutters should be installed to aid in storm water collection.

With a grass swale, less storm water is transported along roads, into catch basins and through the underground storm water system because a greater percentage of the rain is absorbed into the ground. If many secondary roads are located on a site, a reduction in the required capacity of the storm water system with a resultant reduction in construction costs can be achieved.

On roads that require concrete curbs and gutters, Figure 12(b), the rolled curb, should provide the least costly, yet adequate, curb and gutter arrangement. This type is commonly found on commercial and Navy family housing projects, such as the Newport News project. In addition, the rolled curb with slight modification makes an effective transition onto a driveway.

With these guidelines considered, the following modification is recommended:

> 2B.2 d. Curbs and Gutters: *Arterial and collector roads shall be provided with a rolled concrete curb and gutter* of minimum 24" width at each side. Minimum outside radii at intersections shall be 22 feet. All gradients shall provide positive drainage (no ponding). Minimum slope allowance 1.0%. *Secondary roads, including cul-de-sacs, dead ends, lanes and places do not require concrete curbs and gutters. In their place, a well graded and established grass swale can be used. It shall meet the road surface and serve the purpose of positive drainage (no ponding). Minimum slope allowance 1.0%. If a driveway is to meet the road surface, then a rolled concrete curb and gutter or a culvert shall be used for positive drainage.* (6) [Italics added]

Since the RFP criteria for sidewalks states that "sidewalks are desirable," it is not necessary to modify this paragraph. It is assumed that the RFP has already examined the relatively high cost of concrete sidewalks and does not consider them necessary along any site roads. The paragraph also states that "housewalks and streetwalks should be of non-reinforced concrete" which is a practical consideration since these walkways are not structural and do not require reinforcement. (See Appendix D).

Site Utilities And Storm Drainage

Water System

Water Main Design. In the RFP, Paragraph 2B.6 b., Design Criteria, 2B.6 c., Mains, and 2B.6 e., Flow Requirements address the various water system requirements (see Appendix E). Paragraph 2B.6 b. mentions design per the HUD Minimum Design Standards (MDS). It does not consider design based on Average Daily Demand (ADD) as noted in Optimum Value Engineering publications (17).

Paragraph 2B.6 c. mandates a minimum water main size of eight inches, while OVE design techniques recommend a six inch diameter line for water supply and fire protection and smaller diameter lines where no fire protection support is required.

Paragraph 2B.6 e. provides some important water system flow requirements that consider adequate water pressure and fire protection, such as a minimum residual pressure of twenty psi at each fire hydrant and between twenty psi and seventy-five psi at each domestic outlet.

Considering these three paragraphs and the various design techniques described by OVE, it is possible that they can be modified to take advantage of potential cost savings and avoid a water system that may be unnecessarily over designed.

The HUD MDS have been superceded and it is known that NAVFAC is in the process of substituting alternative standards. It is not known, however, if these new standards consider ADD. The following paragraph, therefore, provides recommended changes for the version of paragraph 2B.6 b. which does consider ADD:

> 2B.6 b. Design Criteria: <u>The water distribution system shall be designed in accordance with an average daily demand (ADD) factor for the site location. This ADD shall also consider the peak usage in a development as a maximum design tolerance.</u> All connections will be made by the contractor in accordance with AAWA standards. Mains shall be considered as that part of the water system supplying fire hydrants. Pipes supplying groups of dwelling units exclusively shall be referred to as branches. <u>These branches shall serve more than one unit each with multiple service taps.</u> Polyvinyl chloride (PVC) plastic watermain pipe and fitting and all laterals 4" and larger shall conform to AWWA C900 and shall be plain end of gasket bell end, pressure Class 150 or 200. Fittings shall be gray-iron or ductile iron conforming to AWWA C110 and shall have cement-mortar lining conforming to AWWA C104/A21.4, standard thickness. Install pipe and fittings in accordance with the requirements of UNI B-3 for laying of pipe, joining PVC pipe to fittings and accessories, and setting of hydrants, valves and fittings. Ductile iron watermain pipe shall

> conform to AWWA C151. Mains as well as interior piping shall be disinfected in accordance with AWWA Specification C-601-68 and both done simultaneously. (6) [Italics added]

Paragraph 2B.6 c. can be modified to include reduced sizing of water mains that still satisfy flow and pressure requirements, yet differentiate between lines that support and lines that do not support fire protection. Recommended revisions are:

> 2B.6 c. Mains: Water distribution mains shall be looped with no dead ends and be of adequate size to satisfy both domestic and fire flow requirements. *Minimum allowable size for water distribution mains is six (6) inches where fire protection support is required and four (4) inches where fire flow requirements do not exist.* Connection to an existing system shall be by the Contractor at the locations shown on the drawings. Sufficient sectional control valves shall be provided so that no more than two fire hydrants will be out of service in event of a single break in a water main. (6) [Italics added]

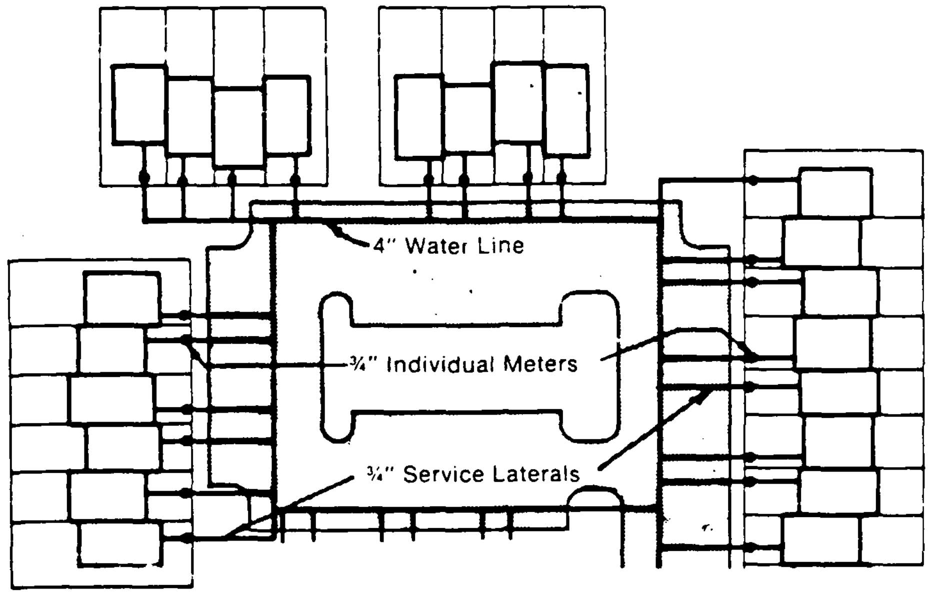
Paragraph 2B.6 e., Flow Requirements, contains design pressure parameters that consider operating functions of fire hydrants and domestic fixtures and appliances for one or two story buildings. The requirements in this paragraph appear to be neither inadequate nor excessive and, therefore, do not require modifications.

Multiple Water Services From a Common Tap. This concept is already very common and widely used by contractors on Navy family housing projects, including the projects in Newport News, Colts Neck and Subic Bay. At Newport News, a single water line services each building, either consisting of four or eight units with several wyes used to supply each unit. At Subic Bay, each group of two units is supplied by a single water service line, in buildings of two, four or six units. Examination of a sample development consisting of four units per building can illustrate the cost differences which are possible if multiple water services from a common tap are used. Figure 26 illustrates the two design approaches.

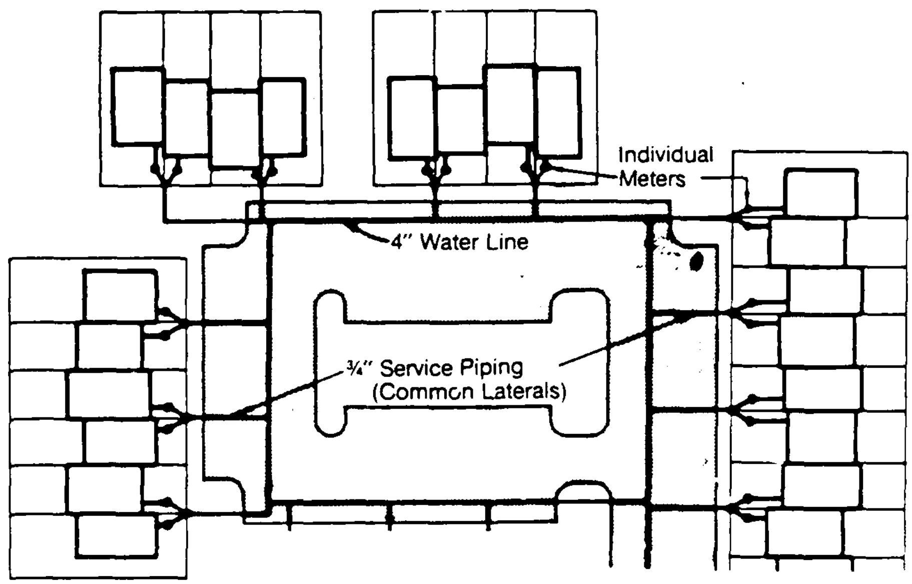
Assume a twenty-five foot distance from the building line to the water main for a total of 100 ft. of water service line for all four units. If one half inch diameter PVC pipe is assumed for each unit at a unit cost of $4.05/lf (22), a total cost of $405 per building is necessary.

If two common taps are used, one for each of the two units, a total of fifty feet of water service line is required. Using a one inch diameter PVC pipe for each pair of units, a unit cost of $4.88/lf (22) results in a subtotal cost of $244 per building. Added to this is five feet of one half inch diameter PVC pipe for each unit service ($4.05/lf). A total cost of $325 per building is, therefore, required.

A total of $80 can be saved on water service lines for just one building of four units. A considerable



(a) Conventional Water Service Connections.



(b) Multiple Water Service Connections From a Common Tap.

Figure 26. Conventional and Multiple Water Service Connections. (From Innovative Site Utility Installations, HUD.)

savings is, therefore, possible for a Navy family housing project of 200-500 units.

The RFP does not specifically mention this practical design technique, yet it has been used extensively by contractors on Navy family housing projects. In order to ensure that all contractors are aware of this design flexibility, the use of common taps should be mentioned. In this regard, wording has been included in Paragraph 2B.6 b., which was previously discussed.

Polyvinyl Chloride (PVC) and Plastic Pipe or Tubing for Service Lines. The use of PVC is permitted in the RFP and used extensively by contractors on Navy family housing projects. Normally, only local jurisdictions have had any effect on requiring that other materials such as copper pipe underslab plumbing be used. This was the case on the Newport News project. Since the RFP does allow the use of PVC, it is not necessary to make any modifications.

Blow-offs Versus Hydrants. One of the NAVFAC Design Manuals (DM-7) referenced in the RFP relates to site utility design and construction. In this manual, it is required that all high points on a water line within a new development have an air relief valve and that all low points have a blow-off valve. The practice, therefore, to use blow-off valves to flush sediment or contaminated water from a water line is already required.

In all cases known to the author, water line systems have supported fire protection and do have blow-off valves at all low points and air relief valves at all high points. It is doubtful that a water main will not support fire protection so this OVE concept does not appear to be applicable in this case. No modifications to the current RFP are, therefore, recommended.

Eliminate Curb Stops. Paragraph 2B.6 h., Curb Stops, specifically states that "Curb stops shall not be used" (see Appendix E). The paragraph further states that each unit shall have its own interior cut-off valve which is readily accessible. Curb stops were originally a maintenance and vandalism problem for Navy Public Works Centers and Departments and were finally determined to be unnecessary. In this regard, the cut-off valve was moved to the unit's interior, in lieu of an exterior meter box as recommended by OVE. (Water meters are not used for each unit in Navy family housing.) No modifications to the RFP are, therefore, recommended.

Joint Trenching of Water and Sewer Lines. Although the RFP does not specifically address joint trenching of water and sewer lines, Design Manual 7 (DM-7) does state that water and sewer lines shall not be installed in joint trenches. Interviews with contractors on Navy family housing projects indicate that some believe that the use of PVC pipe allows joint trenching with a high degree of safety, while others believe that the practice is not wise and should never be used.

Despite HUD's extensive research concerning joint trenching of water and sewer lines, the author does not recommend that this practice be adopted. The possibility of water supply penetration and contamination from sanitary sewer line breaks is considered too great. The use of joint trenching constitutes an unnecessary risk and, therefore, should be avoided. This practice is not common in commercial housing projects and has never been allowed on naval installations. The savings in joint trenching may be deceiving since more care and inspection, and therefore greater costs, could be required with the installation of adjacent water and sewer lines.

Sewer System

Curvilinear Sewer Lines. Paragraph 2B.7 b., Design Criteria, of the RFP states that "Curved sanitary sewers are prohibited" (see Appendix E). The author believes that the use of curvilinear sanitary sewers with PVC pipe would be a practical and innovative technique that could significantly reduce the required number of manholes. Modern sewer line cleaning equipment can still service curvilinear sewer lines (3,4) and there should be no detriment to sewage flow through the sanitary sewer system.

Figure 17 provided a cost comparison between the conventional and curvilinear layouts of gravity sewer systems. In this illustration, a savings of $7200 was projected when curvilinear sewer layout, and fewer manholes, were used. The calculation was based on a portion of a development, approximately fifty units. The savings would be much greater in Navy family housing projects of 200-500 units.

The use of curvilinear sanitary sewers is recommended and can be included in the RFP as follows:

> 2B.7 b. Design Criteria: Sanitary sewage system shall be designed and constructed in accordance with [new design standards to be substituted here]. PVC pipe is preferred. Elastomeric joints for cast iron pipes are acceptable. <u>Curvilinear sanitary sewers with PVC pipe that follow the approximate centerline of the road and topographic contours are permitted. The maximum spacing of manholes with curvilinear sewers is 400 feet.</u> (6) [Italics added]

<u>Reduced Diameter Gravity Sewer Lines.</u> Design criteria for sanitary sewer systems mandates design based upon an average daily per capita flow of 100 gallons per day with a peak hourly factor of four and a minimum flow velocity of two and one half feet per second. There is no requirement to use a specific size of pipe for the sewer main, although there are size requirements for sewer laterals (see Appendix E). Since

the design criteria will size the sewer mains, it does not appear to be necessary to mandate a specific size or allow a minimum size without the benefit of design calculations. No modifications to the RFP are, therefore, deemed necessary.

Common Sewer Service Laterals. Common service laterals are used extensively on Navy family housing projects, as are common taps for multiple water services. A reasonable cost comparison would be similar to the one discussed under multiple water services from a common tap. Since the RFP does not specifically mention this technique, the following modification is recommended:

> 2B.7 e. Sewer Laterals: Sewer lateral lines (connections from interior house sewer lines to main) shall be sized as follows: 4-inch minimum serving one or two units; 6-inch minimum serving three or more units. Only interior house sewer lines may be placed under buildings. *One sewer lateral may service more than one unit and is preferred.* All house sewers under buildings shall be as specified in the paragraph entitled "Plumbing." House sewer lines from any one unit shall not pass under any other unit(s) except for two-story flats where the house sewer line from the upper unit(s) may pass under the floor of the lower unit. Cleanouts shall be provided for all branches at points of change in direction before running out to a main. (6) [Italics added]

Increased Spacing Between Manholes. With the recommended addition of curvilinear sewers, the number of manholes required on the site should be reduced. Increasing the spacing between manholes beyond 400 feet could, however, create maintenance problems for Navy Public Works Centers and Departments.

Large Navy bases have Public Works Centers onboard that generally have the more advanced maintenance equipment, while the smaller Public Works Departments are limited. To allow increased spacing up to 600-800 feet may not be feasible for most Public Works activities since they are limited in terms of maintenance equipment. The RFP does not mention a maximum spacing of manholes.

In order to accomodate the use of curvilinear sewers and optimize the spacing of manholes, the author recommends a maximum spacing of 400 feet. This distance is also the maximum allowed by most building codes (17). This recommendation has been included in the modified paragraph 2B.7 b., Design Criteria, previously discussed.

Cleanouts Versus Manholes. The substitution of cleanouts in place of manholes is a technique that could provide a fully functional, easily maintained, yet less costly sanitary sewer system. In Figure 18, the substitution of four cleanouts in place of manholes could result in a cost savings of approximately $4800, (based on unit costs of $1500 per manhole and $300 per cleanout (17,22)). OVE techniques recommend the use of cleanouts in five applications, which are incorporated into the following new paragraph that can be added to the RFP (6):

> *2B.7 ( ). Sewer Cleanouts: Sanitary sewer cleanouts can be substituted for sewer manholes in the following areas:*
>
> *1. Terminal lines - On short lines between 200 and 300 feet, it may be more practical to install cleanouts instead of manholes since maintenance access is still available through the cleanout on the top end of the line.*
>
> *2. Line Repairs - Cleanouts can be substituted for some manholes on existing lines that require repairs.*
>
> *3. Sewers in Flood-Prone Areas - Where watertight manholes are required in low-lying areas, cleanouts can be substituted since they are not as susceptible to infiltration and are less expensive to install.*
>
> *4. Rocky Terrain - Using cleanouts in lieu of manholes in rocky terrain can significantly reduce excavation and save installation time.*
>
> *5. Short Sewer Lines - Cleanouts can be used in place of several manholes on sewer systems where many horizontal bends require manholes.*
>
> [Italics added]

Electrical System

Common Trenching of Electrical, Telephone, Cable Television and Natural Gas Lines. Joint trenching of these utilities is a very common practice on commercial and Navy family housing projects and is currently permitted to some extent in the RFP. The use of common trenching, however, depends on whether the electrical system is to be underground or overhead, an option left to the contractor in the RFP (see Appendix E).

Based on the widespread use and appeal of underground electrical systems on commercial and Navy family housing projects, it is the author's opinion that underground electrical systems should be mandated in the RFP. The improved site appearance, and more importantly, the savings due to the elimination of maintenance of utility poles, overhead lines and devices subject to weather and accidental damage should pay for the initial higher cost of an underground system in the long term.

In order to mandate an underground electrical system, and incorporate the use of joint trenching, the following modification is recommended:

> 2B.9 b. Design Criteria: *The electrical distribution system shall be designed as an underground system. Service drops shall be underground. The use of direct burial cable is permitted. Installation shall conform to latest applicable rules of the National Electrical Code, NFPA No. 70, the National Electrical Safety Code, ANSI C2, and except as modified herein.* (6) [Italics added]

Common Construction/Ownership of Utility Poles and Trenches. This concept is not applicable to Navy family housing projects since in most cases, housing is built on currently owned Navy property and the maintenance of utility poles and trenches is the sole responsibility of the resident public works activity.

Direct Burial Cable. If an underground electrical system was designed and proposed by a contractor, the use of direct burial cable would be expected since it is now a very common practice and less expensive than conduits or concrete ducts. The Newport News project consisted of direct burial cable exclusively in the underground electrical system and was a less costly and easier to install method for the contractor. If underground electrical systems are to be mandated, as recommended by the author, then the use of direct burial cable should be a natural component of the system. This recommendation has been included in the modification of Paragraph 2B.9 b., Design Criteria, previously discussed.

Installation of Lines Prior to Curb Construction. While this technique has some merit, it borders on mandating construction procedures which is normally avoided in most construction contracts. Because of this and apparently minimal cost savings, its inclusion in the RFP is not recommended.

Natural Gas System

It is noted that natural gas systems are not normally used on Navy family housing projects and were not encountered by the author. With no basis for examination and comparison, natural gas systems are not considered in this research study. If a natural gas system were included in a Navy family housing project, the ideas developed by HUD and NAHB could be considered and included in the applicable design criteria.

Storm Drainage System

Storm Water Management. Paragraph 2B.3, Grading and Drainage, of the RFP addresses the requirements for a storm water drainage system on a development. The design criteria mandates the application of the rational method using a ten year storm frequency and checked against a twenty-five year storm frequency. The criteria also requires that run-off for adjacent sites be included in the storm drainage calculations. These requirements are both practical and sound.

The requirements concerning surface storm drainage and underground storm drainage (see Appendix E) are not considered, however, to be in agreement with the modern view of storm water management. This shortcoming is considered serious and drastic changes are recommended.

For surface storm drainage, the criteria specifically states that "Ponding anywhere on the site will not be accepted." With the research conducted by HUD and NAHB and the systems currently used by many residential developers, a drainage system composed of water collection, retention and slow release from the site is much more practical, more attractive and less costly.

Not all sites will, of course, be able to accomodate a retention pond, or even require one if the annual rainfall is substantially low. In addition, existing drainage paths, streams or ponds on a site are better left undisturbed or improved. This was the case in the Newport News project where an existing storm water drainage easement was upgraded and used to serve as the central storm water collector on the site.

Considering the surface storm drainage system criteria, the following changes are recommended:

> 2B.3 d. Surface Storm Drainage: Provide positive drainage away from buildings. Drainage system shall be properly coordinated with surrounding properties to insure that run-off does not cause damage to other properties. *Retention ponds on site are permitted and shall include a slow release outlet that feeds the municipal storm sewer system.* Surface drainage from unpaved areas shall have collection area limited to maximum of 5,000 square feet. When surface drainage collection area exceeds 5,000 square feet the discharging collection area flow shall be into an underground storm drainage system. Surface drainage shall flow away from each building and no collection swales or open ditches shall be closer than 20 feet to any building. Locate storm water inlets so that no collection swales flow across a street or sidewalk to reach a storm sewer. (6) [Italics added]

Natural Drainage and Unpaved Swales. As proven by OVE research, the maintenance and use of natural drainage paths and the use of unpaved swales can aid in effective surface drainage and minimize the problems associated with covering or altering existing drainage paths. Paragraph 2B.3 a., General, outlines basic design requirements and is a proper area in which to mention natural drainage paths and unpaved swales (see Appendix E).

The following modification is recommended:

> 2B.3 a. General: The Contractor shall confine all work, except grading and drainage, within the project boundaries indicated on the attached drawings. Surface material shall be stripped from building and road sites for reuse in final landscaping. The Contractor is responsible for capping and/or relocation of all storm drainage systems. *The preservation of natural drainage paths is encouraged and shall be investigated by the Contractor during the site design phase. In addition, the use of unpaved drainage swales is also encouraged, providing the swales can accomodate the design runoff determined from the drainage calculations.* (6) [Italics added]

Curvilinear Storm Sewers. Paragraph 2B.3 e., Underground Storm Drainage, states that "Curved sewers are prohibited." The author has not encountered any cases where curvilinear storm sewers have resulted in unusual maintenance problems or been ineffective. Within NAVFAC, the prevailing attitude has been one of unfamiliarity and uncertainty. This is understood, yet there appears to be no reason why this innovative technique should not be permitted, possibly at first on a trial basis. With curvilinear sewers, material and installation costs are reduced and the number of storm manholes and catch basins can be reduced.

The inclusion of curvilinear storm sewers in the RFP is recommended as follows:

> 2B.3 e. Underground Storm Drainage: Collection and disposal systems shall be designed to provide a minimum flow velocity of 3 feet per second when

> flowing half full. Culverts and underground strom drains with free outlets shall be designed with water surface at the inlet at the same elevation as the top of the pipe and the outlet unsubmerged. Design pipes to flow full. Discharge area shall be protected to prevent erosion. Storm drain manholes or catch basins shall be provided at changes in alignment and at junctions with mains or laterals. *Curvilinear storm sewers are permitted providing that they meet industry and manufacturer standards for allowable deflection between concrete pipe sections or allowable bending radii of steel or plastic pipe.* (6) [Italics added]

Maximum Spacing Between Structures. The RFP does not specifically address any limits on spacing between drainage structures, other than in paragraph 2B.3 e. where it states "manholes shall be provided at changes in alignment and at junctions with mains or laterals." It is assumed, therefore, that a designer can use whatever criteria he deems appropriate and effective. In this regard, no modifications to the RFP criteria concerning the storm drainage system are recommended.

Foundations

The required foundation system for the housing project is addressed in paragraph 2D.1, Foundations, under Section 2D. - Construction and Materials. The wording varies from project to project since the type of units to be built and local soil conditions also vary. The reviewing authorities of the RFP, therefore, take these factors into consideration when editing the RFP prior to release. Appendix F contains one example of a foundation design requirement for a Navy family housing project at Adak, Alaska.

Since there is no standard entry for Foundations in the RFP, no specific wording can be recommended for the standard RFP. Since OVE research has dealt primarily with one specific type of foundation, however, those ideas can be summarized to provide at least one example of OVE design techniques. The foundation system to be examined, concrete slab on grade, will be discussed in terms of footings, slab and foundation walls.

Footings and Slabs

OVE provides some very practical and sound ideas concerning footing sizing based on actual soil bearing capacities and for concrete slabs on grade. Navy family housing is mostly one or two story housing, so the guidelines outlined in Table 4 in Chapter Three can apply.

Of the three Navy family housing projects examined by the author, all contained concrete slabs on grade. The slabs all used a thickened edge concept for footing design with reinforcement. Typically, these slabs and footings were also placed monolithically over a prepared gravel subbase. A vapor barrier and welded wire fabric were incorporated. Figure 27 illustrates this design detail.

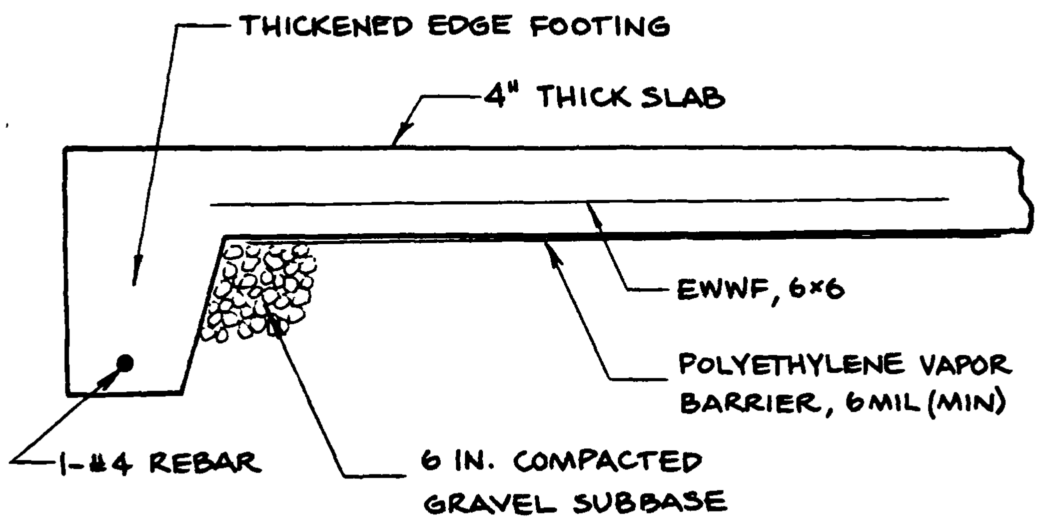


Figure 27. Concrete Slab on Grade - Typical on Examined Navy Family Housing Projects.

Using the concepts outlined in Table 3, the following paragraphs are recommended for use when a housing project requires concrete slab on grade foundations:

> 2D.1 a. *Concrete Slab on Grade Foundations: Concrete footings shall be sized accordingly based on actual soil bearing capacities within the site. The following table can be used in determining footing sizes:*

FOUNDATION FOOTING SIZES

Footing width in inches for typical loads.

Total Design Load lbs/lf footing	Allowable Soil Bearing Capacity, psf 1500	2000	2500	3000
1000	8	6	4.8	4
1500	12	9	7.2	6
2000	16	12	9.6	8
2500	20	15	12	10

> *In cold climates, footings shall extend below the frost line. A monolithic concrete slab, combining the floor and footings in a single pour, is preferred. Slabs shall be 4 inches thick over a granular subbase and vapor barrier. Welded wire fabric within the slab is not required. Control joints shall be used to control shrinkage cracking. In cold climates, slab perimeters shall be insulated with an approved material to prevent excessive heat loss.* [Italics added]

Foundation Walls

Most Navy family housing projects consist of concrete slabs on grade and do not include basements. The author did not encounter any projects with basement foundations, so no actual examination or comparison was possible. Recommended wording for an RFP containing foundation wall criteria can, however, be provided:

> 2D.1 b. *Foundation Walls: Foundation walls may be constructed of concrete blocks, reinforced or non-reinforced concrete or pressure treated wood, based on design calculations and local environmental conditions. Exterior sides of foundation walls below grade shall be treated with a waterproof membrane and a gravity drainage system shall extend around the foundation wall footing perimeter.* [Italics added]

Floor Systems

For second floors of concrete slab foundation buildings and all floors of a building with a basement, the floor system design and construction techniques provided in OVE can be used effectively. Most Navy family housing is either wood framed or metal framed, and both framing techniques can take advantage of the OVE techniques (1).

Current Guidelines

Section 2E., Structural Standards and Design, of the RFP addresses the structural design of the unit. Specifically, paragraph 2E. k. considers Floor Systems requirements (see Appendix F).

It is encouraging to note that this paragraph requires that "Wood flooring systems shall be glued and nailed." This is one of the OVE recommendations for floor systems as it increases the allowable span of the floor, stiffens the floor system and eliminates squeaking. Glue-nailed floor systems were used in the Newport News project. This is the only requirement, however, in this paragraph. There are several other OVE concepts that can be included.

Framing

The use of twenty-four inch on center (o.c.) framing, despite doubt from some contractors about its effectiveness, is still considered a feasible design approach based on the research and Affordable Housing Studies completed by HUD and NAHB. It can easily be coordinated with twenty-four inch o.c. wall and roof framing and should be offered as an alternative to the conventional sixteen inch o.c. framing method.

Another practical framing technique is the use of built-up wood beams for center support. This type of beam was used in the Newport News units since it was less expensive than the alternative steel beam, capable of prefabrication on the site and less expensive to install based on local labor rates. For a metal framed system, the Subic Bay project used a similar built-up metal beam to achieve center support.

The OVE techniques dealing with the elimination or reduction of framing components (Table 7, Items 3 to 7, 9) seem to be questionable and probably unfamiliar to most contractors. It is the author's opinion that there would be a reduction in the quality of the framing if some of these components were eliminated. They are, therefore, not recommended for inclusion in the RFP.

Some of the other OVE techniques that are practical and that reduce unnecessary construction costs are the elimination of bridging, the use of sill anchors instead of anchor bolts and the use of prefabricated floor trusses. These techniques should be specifically included as options in the RFP because they are presently receiving widespread acceptance by residential contractors.

The following paragraph which considers all of the applicable OVE concepts is, therefore, recommended for an RFP dealing with wood or metal framed units:

> 2E.k. Floor Systems: *Wood flooring systems may be 24 in. o.c. framing, yet shall be glued and nailed.* Glue line shall not be considered for stress transfer in diaphragm. *Beams used for center support may be steel or built-up wood. Bridging is not required and the use of sill anchors instead of anchor bolts is permitted. Prefabricated floor truss systems are preferred.* (6) [Italics added]

Wall Systems

OVE techniques related to wall systems include twenty-four inch o.c. framing, elimination of minor framing components and prefabrication. While the use of twenty-four inch o.c. framing has been used in commercial and Navy family housing projects and the use of prefabricated wood and metal wall panels has become very popular, the elimination of minor framing components was not encountered by the author and is probably not a widely accepted practice at the present time.

Framing and Prefabricated Wall Panels

The contractor on the Newport News project objected to twenty-four inch o.c. wall framing because he felt it would possibly highlight the deflections in the individual studs along an entire wall. He felt that if one or more studs were bowed, the sheathing over the framing would pick up the defects and telegraph them along the wall. This would result in an unattractive wall finish which could be avoided if conventional sixteen inch o.c. framing were maintained.

Twenty-four inch o.c. framing was used on the Subic Bay project, and the success of this framing technique was undoubtedly assisted by the use of galvanized metal studs. With metal studs, deflections are not as common as those in wood studs. Consequently, walls will rarely telegraph any defects and instead provide a smooth level finish surface.

One trend that is evident from just these two Navy family housing projects is an apparent difference in the use and performance of wood and metal framed wall systems. Metal members maintain their proportions better than wood members and have fewer, if any, defects. Accordingly, the use of metal members may be better suited than wood members for twenty-four inch o.c. framing.

Whether sixteen inch o.c. or twenty-four inch o.c. framing is used, the use of prefabricated wall panels can save time and costs in the erection of housing units. Prefabrication is a growing concept in the residential market and should eventually become a major part of the home building process.

Prefabricated wall panels have become very popular for residential builders, providing less installation time on site, easier handling and lower material and labor costs. The Subic Bay project used a prefabricated unit concept with metal framing and resulted in expedient erection on site.

Some contractors, such as in the case of the Newport News project, prefer stick-built framing. For that particular area, the contractor believed that due to low labor rates, stick-built construction was actually less expensive than using prefabricated walls from a supplier.

Although the opinions regarding prefabricated wall panels may vary, their popularity and acceptance is apparent. While the RFP should not mandate the use of prefabricated panels, the author feels that it should highlight the option for contractors. Considering the facts concerning sixteen inch o.c. versus twenty-four inch o.c. framing and prefabricated wall panels, the following new paragraph is recommended for addition to the RFP: (Note: The RFP does not currently have an existing entry concerned with Wall Systems.)

> 2E.( ) Wall Systems: For wood wall systems, 16 in. o.c. framing is preferred. For metal wall systems, 24 in. o.c. framing is permitted. Prefabricated wood or metal wall panels may be used. [Italics added]

Elimination of Framing Components

The elimination of various framing components, such as top plates, partition posts, mid height blocking, interior window trim and the use of a two stud corner, are probably unfamiliar to most contractors. None of the Navy family housing projects examined used these OVE techniques. It was the opinion of the contractor on the Newport News project that a transition to this style of framing could create quality problems and be difficult to implement effectively. Accordingly, the use of these OVE techniques is not recommended and was not mentioned in the previously discussed RFP paragraph.

Roof Systems

Prefabricated Roof Trusses

The most substantial innovation in roof system design and construction has probably been the development and use of prefabricated roof trusses. Prefabricated roof trusses are practically a standard in residential construction, supplied by many manufacturers and used by large and small contractors.

Prefabricated metal roof trusses were used on the Subic Bay project and wood roof trusses were used on the stick-built Newport News project. Used in many commercial housing projects, prefabricated roof trusses are apparently one building innovation that has gained a wide range of acceptance.

In the RFP, only design criteria, such as dead, live and weather loads, and design standards are discussed. There are no specific entries dealing with construction or installation. Even though prefabricated roof trusses are widely used, it is recommended that their preferred use, based on cost savings studies by HUD and NAHB, be indicated in a new paragraph in the RFP as follows:

> 2E. ( ) Roof Systems: *Prefabricated wood or metal roof trusses are preferred, engineered on the basis of the design criteria. As part of the roof system design, a ventilation system shall be provided that adequately ventilates all attic spaces to the exterior.* [Italics added]

Other Innovations

Elimination of Roof Overhang. The elimination of the rake overhang on a gable roof or the elimination of the entire roof overhang are two of the other roof system innovations developed in OVE. Their application to most housing projects, however, may be limited due to the design of the soffit, fascia and ventilation system. If a soffit ventilation system is proposed by a designer, eliminating roof overhang would not be feasible.

As discussed under solar orientation in Chapter Three, a roof overhang can be very effective in providing shade over a window during the summer months when the sun is at a high angle. In addition, the overhang can also provide an extra measure of weathertightness that a flush roof and exterior wall would not.

While a design that includes no roof overhang could be proposed by a designer and be acceptable to the Navy, it is not necessary to highlight this design feature in the RFP. The feature is one that detracts from the appearance of a unit by not providing varying roof lines and dimensions and would probably not be preferrable to the Navy.

Gable End Ventilation. As discussed in Chapter Three, adequate roof ventilation is important in roof system design in order to avoid problems in the winter months in temperate regions. One very effective method of ventilating attic spaces is with gable end vents, constructed of aluminum or plastic.

The Newport News project used aluminum gable end vents on all building groups and it appeared that this method was probably the most cost effective way to ventilate attic spaces. Attic ventilation should be a design requirement in any roof system and it should be mandated in the RFP. By mandating attic ventilation, contractors could select gable end vents or a similar design concept. The requirement for attic ventilation is, therefore, included in the paragraph on Roof Systems previously discussed.

Support Systems

Section 2F of the RFP, Mechanical, Electrical and Plumbing, provides exceptional detail in the discussion of the requirements for the support systems in Navy family housing. Each support system is divided into design standards and equipment requirements (see Appendix B).

In reviewing the specific paragraphs of the RFP and the OVE design and construction techniques dealing with support systems, there are several key concepts in each support system that could contribute to obtaining more affordable housing.

For the plumbing system, the downsizing of waste drains and vents, the optimum arrangement of fixture groups and the use of prefabricated utility cores are relevant. The electrical system design concepts which promote 15-A circuit breakers and the Smart House theory are points to consider. In addition, the proper sizing of the ducts in an HVAC system can reduce construction and operation costs.

Plumbing

Paragraph 2F.3 of the RFP discusses plumbing for Navy family housing. The reference code is the *National Plumbing Code* (*NPC*) and criteria and guidelines are provided for all components of a plumbing system, as well as the appropriate design calculations.

While several of the paragraphs consider the material composition of the plumbing system components, a paragraph discussing the sizing of the plumbing system, specifically the sanitary waste drains and vents does not exist. One of the key concepts developed by HUD and accepted by part of the industry was the downsizing of the waste drains and vents.

In order to take advantage of this accepted development, a reference in the RFP to the standards either developed by HUD or to the modified *CABO Code* would be appropriate. A possible modification would be to paragraph 2F.3 a., Code, as follows (see Appendix F):

> 2F.3 a. Code: The plumbing system shall conform with the applicable rules of the *National Plumbing Code* (ASME A40.8-55), governing backventing of plumbing fixtures, sizing of waste, vents, drains, and water systems, *or in the case of the Council of American Building Officials (CABO) Code for the sizing of sanitary waste drains and vents.* (6) [Italics added]

In addition to the possible downsizing of the sanitary waste drains and vents, the optimum arrangement of fixture groups is a very popular and cost effective construction method. The Subic Bay project, consisting of prefabricated housing, used this approach in conjunction with the kitchen utility core concept which resulted in quick and efficient connection and testing of the plumbing system in each unit.

One concern over this type of arrangement is maintenance, yet within NAVFAC, there are no maintenance records or findings at this time dealing with back-to-back and clustered plumbing arrangements. Assuming that the maintenance problems may actually be minimal, it is then recommended that the RFP highlight this OVE innovation as well as the utility core concept which is based on the clustered plumbing arrangement method.

The following new paragraph is, therefore, recommended as an addition to the RFP:

> 2F.3 ( ). *Plumbing Arrangements: The design of back-to-back plumbing fixture groups within common walls or between adjacent floors is recommended. Utility cores may also be used to minimize plumbing runs.* (6) [Italics added]

Electrical

The downsizing of some electrical circuits to include a 15-A circuit breaker can result in a significant cost savings in a large multifamily housing project, such as the Newport News Project. On that project, 15-A circuit breakers were used on lighting circuits in each unit with a resultant savings of $6000 compared to the use of 20-A circuit breakers.

The National Electrical Code (NEC) does not have any restrictions on using 15-A circuit breakers for lighting circuits in residential units. Instead, only requirements for adequate overcurrent protection are outlined (26). The 15-A circuit breakers on lighting circuits provide the necessary protection.

The concept of the Smart House, still in the developmental stage, is an innovation that could result in significant cost savings and revolutionize electrical system design in housing units. Although the concept cannot be referenced in a contract document, such as the RFP, at this time, it is a development that NAVFAC should monitor and possibly include in future housing contracts after the development is completed.

HVAC

Request For Proposal requirements on HVAC systems primarily reference the applicable guidelines contained in the National Electrical Code (NEC), the American Society of Heating, Refrigerating and Air Conditioning Engineering Guide (ASHRAE) and the American National Standards Institute (ANSI). There is minimal reference to the duct system design or installation.

Both the Newport News and Subic Bay projects used flexible duct for HVAC air distribution, which is the standard product now used in residential construction. Eight inch insulated flexible duct costs approximately $3.70/lf for material and installation (22). Galvanized metal duct, however, costs approximately $4.80/lf for material and installation (22) and is much more difficult and time consuming to install and test. In addition, maintenance costs are greater for metal duct in humid or tropical climates due to continual condensation and leaking.

In a unit requiring fifty lf of air distribution duct, eight inch flexible duct and galvanized metal duct would cost approximately $185 and $240, respectively. A savings of $55 per unit on a large Navy family housing project would, of course, be significant.

Although the RFP makes no direct reference to this type of duct material, it should be included in order to bring the RFP up to modern standards and to avoid the use of possibly more expensive and less effective materials. In this regard, the following modified paragraph is recommended:

> 2F.3 k. Air Distribution: *Air distribution ducts shall be flexible duct and sized based on the heat-loss calculations computed for each type of unit in the project.* (6) [Italics added]

OVE techniques highlighted the fact that accurate heat-loss calculations for each room in a unit can better determine the required size of HVAC equipment and accessories. In the modified paragraph for air distribution above, reference was made to these heat-loss calculations. In addition, paragraph 2F.1 o., Calculations, should be modified as follows (see Appendix F):

> 2F.1 o. Calculations: The successful proposer (Contractor) shall furnish calculations substantiating the final mechanical designs. *These calculations shall include accurate heat-loss calculations for each room in the unit and for each type of unit in the project, and be used to size equipment and duct systems accordingly.* (6) [Italics added]

Building Materials

Many of the innovative building materials listed in Table 10 have been and are currently being used on Navy family housing projects. While structural particleboard has not gained wide acceptance, flexible HVAC duct, plastic piping, plastic electrical utility boxes, direct burial cable and PVC water and sanitary sewer line piping are now practically standard construction materials. Most of these items were used on the Newport News, Subic Bay and Colts Neck projects. Most of these materials have also been referenced in the previously discussed RFP paragraphs in this chapter, and there is no need to develop a specific section on building materials.

It is noted, however, that with the continual development of new construction materials, NAVFAC should continue to examine, research and possibly adopt new ideas and materials. As new ideas and materials are accepted, the RFP should be updated to include the option or the requirement to use the proven cost effective construction methods.

Summary

This chapter has examined the applicability of Optimum Value Engineering design and construction techniques to the U.S. Navy's housing construction contract Request For Proposal. The eight major subdivisions of innovative building practices developed and described by OVE have been discussed individually and recommendations on the wording of the RFP to include selected techniques have been made.

Chapter Six, Results and Conclusions, summarizes the recommended modifications by describing the interface between OVE and the RFP illustrated in Figure 2. This interface is defined primarily by the available potential for NAVFAC to adopt these cost saving methods and principles and continue to monitor and assess affordable housing.

Beyond recommendations, however, the modifications have to be instituted into the RFPs used on future housing contracts and additional studies need to be completed to assess the actual affects on affordability. These ideas and other recommended studies are also discussed in Chapter Six.

CHAPTER SIX

RESULTS AND CONCLUSIONS

This chapter summarizes the recommended Request For Proposal modifications discussed in Chapter Five that considered Optimum Value Engineering design and construction techniques. A table of recommended techniques is provided for each of the eight residential construction subdivisions defined by OVE. In addition, based on the recommended techniques, the interface between the RFP and OVE illustrated in Figure 2 is discussed.

The final section of the chapter discusses possible directions of future research related to OVE and U.S. Navy family housing. Recommended research studies are necessary to implement and assess the impact of OVE on future housing projects and depend on the efforts of NAVFAC officials and interested student researchers.

Recommended Modifications

Table 12, Summary of Recommended Modifications, summarizes the recommended modifications that consider Optimum Value Engineering. In the table, each OVE subdivision is identified in terms of each recommended technique and the Request For Proposal paragraphs that are affected. With the emphasis placed on Site Design and Development and Site Utilities and Storm Drainage,

Table 12

Summary of Recommended Modifications

OVE Subdivision	Technique(s)	Applicable RFP Paragraph
1. SITE DESIGN & DEVELOPMENT		
	Clustering of units Curvilinear streets Solar and wind orientation	2B.1b., Building Arrangements
	Environmental enhancement	2.B10c., Existing Trees
	Reduced pavement widths	2.B2b., Street Width Criteria
	Reduction or elimination of curbs and gutters	2B.2d., Curbs and Gutters
2. SITE UTILITIES & STORM DRAINAGE		
	Water main design, (ADD and multiple service taps)	2B.6b., Design Criteria
	Water main design, (sizing)	2B.6c., Mains
	Curvilinear sanitary sewers, PVC pipe, maximum manhole spacing	2B.7b., Design Criteria
	Common sewer service laterals	2B.7e., Sewer Laterals
	Cleanouts vs. manholes	2B.7()., Sewer Cleanouts
	Underground electrical system, direct burial cable	2B.9b., Design Criteria

Table 12

(Continued)

OVE Subdivision	Technique(s)	Applicable RFP Paragraph
2. SITE UTILITIES & STORM DRAINAGE		
	Retention ponds	2B.3d., Design Criteria
	Natural drainage paths and unpaved swales	2B.3a., General
	Curvilinear storm sewers	2B.3e., Underground Storm Drainage
3. FOUNDATIONS		
	Footing sizing based on actual soil bearing capacity, monolithic slab and footings, WWF, control joints, slab perimeter insulation	2D.1a., Concrete Slab on Grade Foundations
	Concrete block, concrete or pressure treated wood walls	2D.1b., Foundation Walls
4. FLOOR SYSTEMS		
	24" o.c. framing, glue-nailed subflooring, built-up center beams, sill anchors vs. anchor bolts, prefabricated floor trusses	2E.k., Floor Systems

Table 12

(Continued)

OVE Subdivision	Technique(s)	Applicable RFP Paragraph
5. WALL SYSTEMS		
	24" o.c. framing, prefabricated wall panels	2E.()., Wall Systems
6. ROOF SYSTEM		
	Prefabricated roof trusses, gable end ventilation	2E.()., Roof Systems
7. SUPPORT SYSTEMS		
	Downsizing of plumbing sanitary waste drains and vents	2F.3a., Code
	Optimum arrangement of plumbing fixture groups, utility core design	2F.3()., Plumbing Arrangements
	Flexible HVAC duct material, accurate heat-loss calculations	2F.3k., Air Distribution
	Accurate heat-loss calculations	2f.lo., Calculations
8. BUILDING MATERIALS		
	Incorporated wherever possible into the first eight OVE subdivisions.	

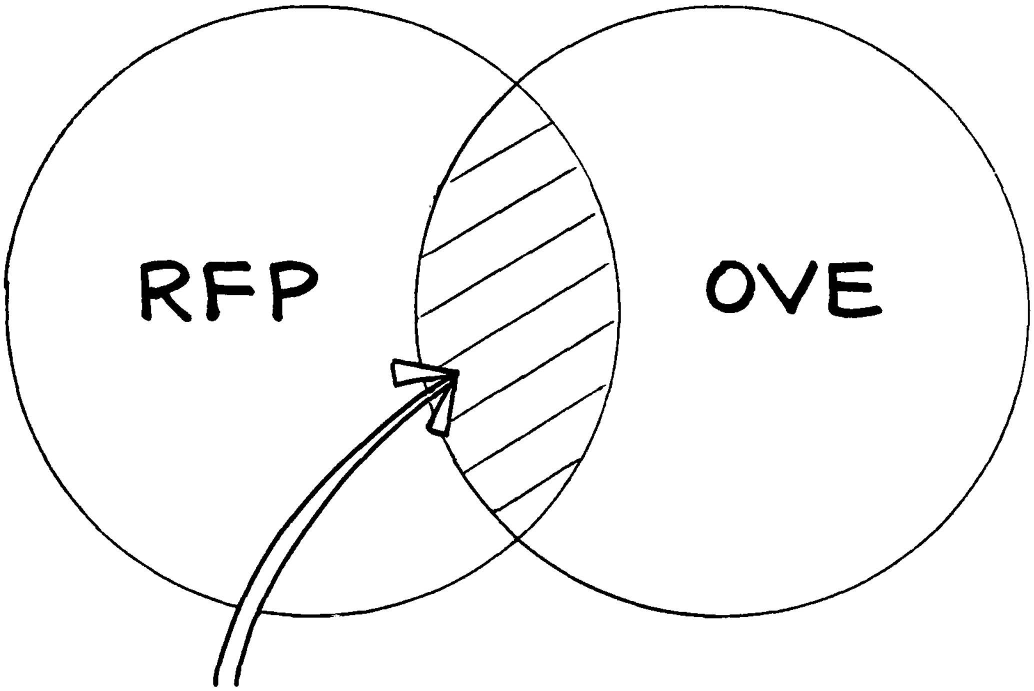
it is evident that more of the innovative design and construction techniques are applied in these two areas, since they represent the greatest potential for cost saving methods in Navy family housing.

Interface Between OVE and the RFP

Figure 2 illustrated the interface between OVE and the RFP. As evident by the content in Chapter Five, this interface represents the actual inclusion of selected OVE design and construction techniques in the U.S. Navy RFP and the assessment of these modifications in future Navy housing contracts. Figure 28 elaborates on this interface and indicates the basis for future research.

Based on the discussion and recommended modifications contained in Chapter Five, several conclusions concerning the interface between OVE and the RFP are provided:

1. As explained by HUD and NAHB officials, the greatest potential for cost savings on a residential housing project is in the areas of (a) Site Design and Development and (b) Site Utilities and Storm Drainage. The emphasis in Chapter Five was within these two areas, with most of the recommended RFP modifications coming from these two subdivisions.



<u>INTERFACE</u>: THE INCLUSION OF SELECTED OVE DESIGN AND CONSTRUCTION TECHNIQUES IN THE HOUSING CONSTRUCTION CONTRACT RFP AND THE ASSESSMENT OF THESE MODIFICATIONS IN FUTURE NAVY FAMILY HOUSING CONTRACTS.

(1) DO THE MODIFICATIONS RESULT IN REDUCED CONSTRUCTION COSTS AND MORE AFFORDABLE HOUSING FOR THE U.S. NAVY?

(2) CAN THE RFP BE FURTHER IMPROVED WITH PROVEN EFFECTIVE OVE AND OTHER INNOVATIVE TECHNIQUES?

Figure 28. The Relationship Between OVE and the RFP.

It appears that a thorough and detailed cost analysis of several projects using and not using the recommended OVE techniques could indicate if any cost savings are indeed possible. The difficulty with such a study, however, is to first change the RFP and ensure that the recommended modifications are used on Navy family housing projects.

The formal modification of the RFP must occur at NAVFAC and be forwarded to all subordinate activities. With this initial study, it has been determined that there are several areas in which OVE can be used and could probably reduce design and construction costs. The next critical step is to implement the modifications. Further research on this topic can then assess the affects of OVE in the residential construction process administered by the U.S. Navy.

2. In conjunction with the emphasis placed on the two site design and development phases discussed above, the distribution of quality points could be revised in order to assign more weight and points to these two important areas. Accordingly, it is recommended that the following modified quality point distribution for 1000 rating points be used:

Site Design	25%
Site Engineering	15%
Dwelling Unit Design	45%
Dwelling Unit Engineering and Specifications	15%
Technical Evaluation Total	100%

This recommended modification should be provided in the RFP for proposer information, as discussed in Chapter Two.

3. While this study serves as an initial assessment of OVE applicability to the Navy family housing contract RFP, continued research in order to maintain the interface between OVE and the RFP is necessary. As technology in residential design and construction changes, so must the criteria and guidelines in the RFP. A continual review of this technology is, therefore, required in order to update the Navy's design and construction standards. Developing technology, such as The Smart House concept in electrical design, is an example of a future innovation that could greatly impact residential construction.

Future Research

This research study has described Optimum Value Engineering design and construction techniques as developed by HUD and NAHB and has explained the housing construction contract process used by the Naval Facilities Engineering Command. While this study has completed the initial introduction of OVE to the Navy family housing RFP, further research is required to accurately assess possible improvements and long term effects.

The following topics of possible future research are recommended as further steps in the analysis of the OVE-RFP relationship:

1. Implement the recommended RFP modifications into future RFPs and assess the acceptance of the modifications among U.S. Navy officials and contractors.

2. Complete a cost analysis of an actual Navy family housing project that uses the recommended RFP modifications and another project that does not use the modifications.

3. Redesign a submitted housing project based on the current RFP and then estimate the cost savings that would be realized with OVE design and construction techniques.

4. Complete a specific cost analysis concerning facilities maintenance of Navy family housing units that have been constructed and have not been constructed in accordance with OVE techniques.

5. Complete a specific cost analysis of Navy family housing projects that use overhead and

underground electrical distribution saystems. The analysis should include actual design and construction costs and short term and long term maintenance costs.

6. Complete a specific cost analysis of Navy family housing projects that protect existing trees compared with projects that do not retain existing trees. Examine the differences in construction costs for the contractor and maintenance costs for the Navy.

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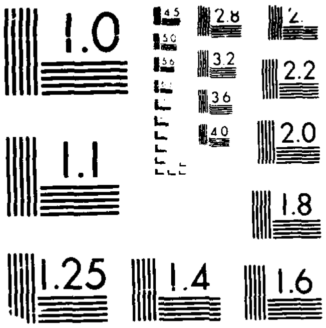
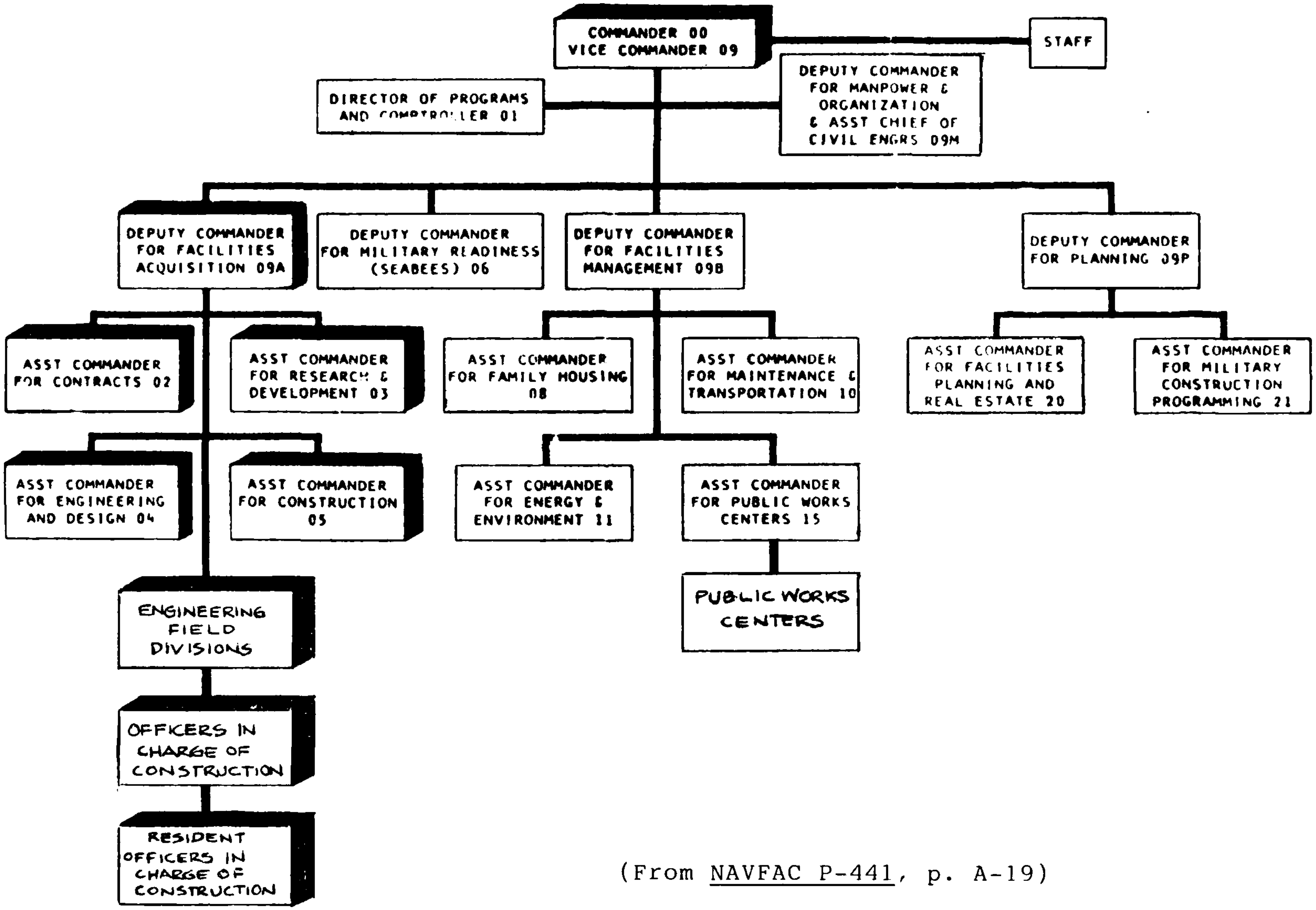


MICROCOPY RESOLUTION TEST CHART

APPENDIX A

NAVAL FACILITIES ENGINEERING COMMAND (NAVFAC) ORGANIZATIONAL STRUCTURE

Naval Facilities Engineering Command Headquarters



(From NAVFAC P-441, p. A-19)

APPENDIX B

REQUEST FOR PROPOSAL (RFP) TABLE OF CONTENTS

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SPECIFICATION 12-84-2569

SECTION 1 - GENERAL

SECTION 2 - DESIGN AND CONSTRUCTION:

SECTION 3 - CONTRACTOR QUALITY CONTROL

SECTION 4 - STANDARD TECHNICAL EVALUATION MANUAL FOR TURNKEY NAVY FAMILY HOUSING PROJECTS

See Section 1, paragraph 1A.2 for additional items comprising RFP.

APPENDIX C

MEETING/SITE VISIT AGENDA

MEETING/SITE VISIT

20 August 1987

PURPOSE: To conduct research for a graduate school thesis in Civil Engineering from The Pennsylvania State University.

Thesis title: "The Application of Optimum Value Engineering Design and Construction Principles To The U.S. Navy's Housing Construction Contract Request For Proposal"

* *

Optimum Value Engineering (OVE)

A procedure for comparing alternative materials and methods in construction to determine the least costly combination that will result in an acceptable product. In residential construction, this results in selecting certain house designs, materials and products that represent the least costly and still acceptable combination in terms of safety and quality.

OVE was initially developed by the National Association of Home Builders (NAHB) Research Foundation through a contract from the U.S. Department of Housing and Urban Development. The purpose of the contract was to reduce home building costs through engineering considerations of common and available building materials and labor skills.

DISCUSSION ITEMS:

SITE DESIGN & DEVELOPMENT

* Reduced lot sizes and setbacks; Zero Lot Line
* Clustering of units
* Solar and wind orientation of units
* Environmental enhancement
* Curvilinear streets
* Reduced pavement widths
* Reduce or eliminate curbs, gutters and sidewalks

SITE UTILITIES & STORM DRAINAGE

* Water system design
* PVC pipe
* Joint trenching
* Sewer system design
* Curvilinear sewers
* Cleanouts vs. manholes
* Electrical system design

* Common trenching of electrical, telephone, CATV and gas lines
* Direct burial cable
* Natural gas system design
* Storm drainage design
* Retention ponds ("Storm Water Management")
* Curvilinear storm sewers

FOUNDATIONS

* Footings
* Foundation Walls
* Slabs
    * Eliminate WWF, vapor barriers and subbase
    * Reduced slab thickness

FLOOR SYSTEMS - WALL SYSTEMS - ROOF SYSTEMS

* Prefabricated floor trusses, walls and roof trusses
* 24" o.c. framing
* Reduced components (sill plate, partition posts, bridging, 3-stud corner, stairwell framing)

SUPPORT SYSTEMS

* Plumbing, Electrical and HVAC design
* Utility cores; common wall plumbing
* Use of 15-A circuits
* Reduced number of circuits, switches, receptacles and light fixtures
* Ventilation
* Innovative techniques and materials

BUILDING MATERIALS

* Structural particleboard
* Flexible duct
* Others

LT Michael A. Giorgione
Civil Engineer Corps
United States Navy

APPENDIX D

REQUEST FOR PROPOSAL (RFP) CRITERIA:
SITE DESIGN AND DEVELOPMENT

2B. SITE DESIGN AND CONSTRUCTION

2B.1 GENERAL:

a. *PLANNING:* This project, consisting of 400 Family Units, shall be developed within the project limits indicated on the enclosed drawings. These drawings indicate existing topography, existing conditions and locations of existing utilities. The enclosed Soil Data, including logs of exploration locations, is intended for preliminary design use. The successful proposer will be responsible for verification of actual Soil conditions present at each site location prior to commencing final design.

b. BUILDING ARRANGEMENTS: Building arrangements should be informal and imaginative with setbacks and orientation to provide for the best view, privacy, and variety. Variety in groupings, arrangements, and siting configurations of buildings is encouraged to fit varying conditions and to provide attractive residential patterns and streetscapes. Rigid, gridiron-like street and building layouts are undesirable. Planning shall take into consideration natural characteristics of the environs, climatic conditions, and prevailing winds. Design should capitalize upon economies inherent in the natural characteristics of the site, reducing street frontage, and consolidating utilities and common open spaces. The proper grouping of units will provide backyard screening, separation of pedestrian and vehicular traffic, recreation, and natural open spaces. Clearance between adjacent buildings shall consider requirements for fire protection, safety, convenience of pedestrians, privacy, and emergency access. Proposers are encouraged to consider energy conservation when developing their proposed building arrangements. Appropriate buffer areas suitable for landscapiong shall be provided to separate and screen from undesirable external influences.

b. STREET WIDTH CRITERIA:

MINIMUM STREET WIDTH (FEET)

Type of Street	No. Units Sited on Street	Units Sited One Side	Units Sited Both Sides
Main Collector Streets	27	35	43
Secondary Streets	23	31	39

Minimum street width is from back of curb to back of curb.

c. CUL-DE-SAC: Cul-de-sac street design is considered undesirable for this project. However, a cul-de-sac shall be provided at all dead-end streets and street shall not exceed 500 feet in length, measured from the center of the cul-de-sac turnaround, to the center of the nearest collector street intersection. Minimum cul-de-sac radii shall be 50 feet. Contractor shall make adequate provision in cul-de-sacs for snow removal and storage.

d. CURB AND GUTTERS: Streets shall be provided with a concrete curb and gutter of minimum 24" width at each side. Minimum outside gutter radii at intersections shall be 22 feet. All gradients shall provide positive drainage (no ponding). Minimum slope allowable 1.0%.

h. SIDEWALKS: Sidewalks are desirable. Sidewalk shall be a minimum of 4 feet wide. Housewalks, other pedestrian walkways, and bike paths, shall be a minimum of 3 feet wide. Joints in sidewalks and curbs shall be the following types and widths: 1/4" weakened plane joints at 15 feet on center; 1/2" expansion joints at 60 feet on center; and 1/4" scored joints shall also occur at curb returns. Housewalks and streetwalks shall be of non-reinforced concrete with a minimum nominal thickness of 4 inches. Other miscellaneous walkways shall be surfaced as appropriate for their intended use. Walkways to shopping and recreation areas are desirable.

2B.10 LANDSCAPING:

a. GENERAL: New plantings of trees and shrubs will not be a part of this contract, but design for and planting of new trees, shrubs, and irrigation may be included as part of successful proposer's contract. Landscaping shall consist of grass or ground cover only and shall be of varieties having compatibility with existing soils and climate. All grass or ground cover shall be guaranteed through one growing season. Contractor shall be responsible for proper care of ground cover for the period of time required for its establishment or 90 days after seeding has been completed for the entire project, whichever is longer. The entire housing area, within the limits of construction, shall present a neat and finished appearance. Lawn sprinkler systems are prohibited.

b. LANDSCAPING PLAN: The landscaping plan shall describe all grass or ground cover and soil amendments to be included in the proposal.

c. EXISTING TREES: Not used.

APPENDIX E

REQUEST FOR PROPOSAL (RFP) CRITERIA: SITE UTILITIES AND STORM DRAINAGE

2B.3 GRADING AND DRAINAGE:

a. GENERAL: The Contractor shall confine all work, except grading and drainage, within the project boundaries indicated on the attached drawings. Surface material shall be stripped from building and road sites for reuse in final landscaping. The Contractor is responsible for capping and/or relocation of all storm drainage systems.

b. DESIGN CRITERIA: Storm drainage shall meet HUD Minimum Property Standards. Design shall be by the rational method using 10 year storm frequency and checked against 25 year storm frequency. All runoff onto the site from adjacent properties shall be included in the storm drainage calculations.

c. MINIMUM GRADES: Surface drainage:

1.0% gutters and small lined ditches
2.0% small unlined swales
1.0% area drainage of paved surfaces
2.0% area drainage of unpaved areas
5.0% in first 10 feet away from unit

d. SURFACE STORM DRAINAGE: Provide positive drainage away from buildings. Drainage system shall be properly coordinated with surrounding properties to insure that run-off does not cause damage to other properties. Ponding anywhere on the site will not be accepted. Surface drainage from unpaved areas shall have collection area limited to maximum of 5,000 square feet. When surface drainage collection area exceeds 5,000 square feet the discharging collection area flow shall be into an underground storm drainage system. Surface drainage shall flow away from each building and no collection swales or open ditches shall be closer than 20 feet to any building. Locate storm water inlets so that no collection swales flow across a street or sidewalk to reach a storm sewer.

e. UNDERGROUND STORM DRAINAGE: Collection and disposal systems shall be designed to provide a minimum flow velocity of 3 feet per second when flowing half full. Culverts and underground storm drains with free outlets shall be designed with water surface at the inlet at the same elevation as the top of the pipe and the outlet unsubmerged. Design pipes to flow full. Discharge area shall be protected to prevent erosion. Storm drainage manholes or catch basins shall be provided at changes in alignment and at junctions with mains or laterals. Curved sewers are prohibited.

2B.6 WATER DISTRIBUTION SYSTEM:

a. GENERAL: Contractor shall provide new water distribution system for this project and connect to existing system indicated on the drawings. The Contractor is responsible for capping and/or relocation of all disturbed existing water systems.

b. DESIGN CRITERIA: All connections will be made by the Contractor to the water distribution system which shall be designed and constructed in accordance with Section CW 1300, HUD Handbook, Minimum Design Standards for Community Water Supply system, HUD 4940.2 with latest revisions except as modified herein. Mains shall be considered as that part of the water system supplying fire hydrants. Pipes supplying groups of dwelling units exclusively shall be referred to as branches. Polyvinyl chloride (PVC) plastic watermain pipe and fittings and all laterals 4" and larger shall conform to AWWA C900 and shall be plain end of gasket bell end, pressure Class 150 or 200. Fittings shall be gray-iron or ductile iron conforming to AWWA C110 and shall have cement-mortar lining conforming to AWWA C104/A21.4, standard thickness. Install pipe and fittings in accordance with the requirements of UNI B-3 for laying of pipe, joining PVC pipe to fittings and accessories, and setting of hydrants, valves and fittings. Ductile iron watermain pipe shall conform to AWWA C151. Mains as well as interior piping shall be disinfected in accordance with AWWA Specification C-601-68 and both done simultaneously.

c. MAINS: Water distribution mains shall be looped with no dead ends and be of adequate size to satisfy both domestic and fire flow requirements. Minimum allowable size for water distribution mains is eight (8) inches. Connection to an existing system shall be by the Contractor at the locations shown on the drawings. Sufficient sectional control valves shall be provided so that no more than two fire hydrants will be out of service in event of a single break in a water main.

2B.6 WATER DISTRIBUTION SYSTEM:

e. FLOW REQUIREMENTS: System design shall provide a minimum residual pressure of 20 p.s.i. at each fire hydrant. Water must be supplied by mains of appropriate capacity to provide 500 g.p.m. at one story units and 750 g.p.m. at two story structures. This is mandatory flow over and above domestic requirements. Domestic pressure shall be a minimum of 20 p.s.i. and a maximum of 75 p.s.i. at each outlet after allowing for friction, elevation, and other pressure losses. Provide a pressure reducing valve (PRV) when water main pressures are higher that 75 p.s.i.. All plugs, caps, tees, bends, and hydrants on water mains and hydrant laterals shall be provided with reaction backing or movement prevented by attaching metal tie rods or clamps.

h. CURB STOPS: Curb stops shall not be used. Each dwelling unit shall be provided with a separate interior service main cut-off valve readily accessible, but not exposed in the living areas.

2B.7 SANITARY SEWAGE SYSTEM:

a. GENERAL: Contractor shall provide a new sewage system and connect to the existing sewer indicated on the drawings. The Contractor is responsible for capping and/or relocation of all disturbed existing sewage systems.

b. DESIGN CRITERIA: Sanitary sewage system shall be designed and constructed in accordance with Sections CS400, CS500, CS12000, HUD Guide Minimum Design Standards for Community Sewerage Systems, HUD 4940.3 with latest revisions, except as modified herein. PVC pipe is preferred. Elastomeric joints for cast iron pipes are acceptable. Curved sanitary sewers are prohibited.

e. SEWER LATERALS: Sewer lateral lines (connections from interior house sewer lines to main) shall be sized as follows: 4 inch minimum serving one or two units; 6 inch minimum serving three or more units. Only interior house sewer lines may be place under buildings. All house sewers under buildings shall be as specified in the paragraph entitled "Plumbing." House sewer lines from any one unit shall not pass under any other unit(s) except for two-story flats where the house sewer line from the upper unit(s) may pass under the floor of the lower unit. Cleanouts shall be provided for all branches at points of change in direction before running out to a main.

2B.9 ELECTRICAL DISTRIBUTION SYSTEM:

b. DESIGN CRITERIA: The electrical distribution system may be designed as an underground or overhead system. Service drops shall be underground. Installation shall conform to latest applicable rules of the National Electrical Code, NFPA No. 70, the National Electrical Safety Code, ANSI C2, and except as modified herein.

APPENDIX F

REQUEST FOR PROPOSAL (RFP) CRITERIA: FOUNDATIONS, FLOOR SYSTEMS AND SUPPORT SYSTEMS

2D. CONSTRUCTION AND MATERIALS

2D.1 BUILDING EXTERIORS:

a. FOUNDATIONS: Footings shall be concrete grade beams over wood piles at Site 1, or continuous spread footings at Sites 2 and 3. Foundation walls shall be concrete construction.

k. FLOOR SYSTEMS: Wood flooring systems shall be glued and nailed. Glue line shall not be considered for stress transfer in diaphram.

2F.3 PLUMBING:

a. CODE: The plumbing system shall conform with the applicable rules of the National Plumbing Code (ASME A40.8-55), governing backventing of plumbing fixtures, sizing of waste, vents, drains, and water systems.

o. CALCULATIONS: The successful proposer (Contractor) shall furnish calculations substantiating the final mechanical designs.

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