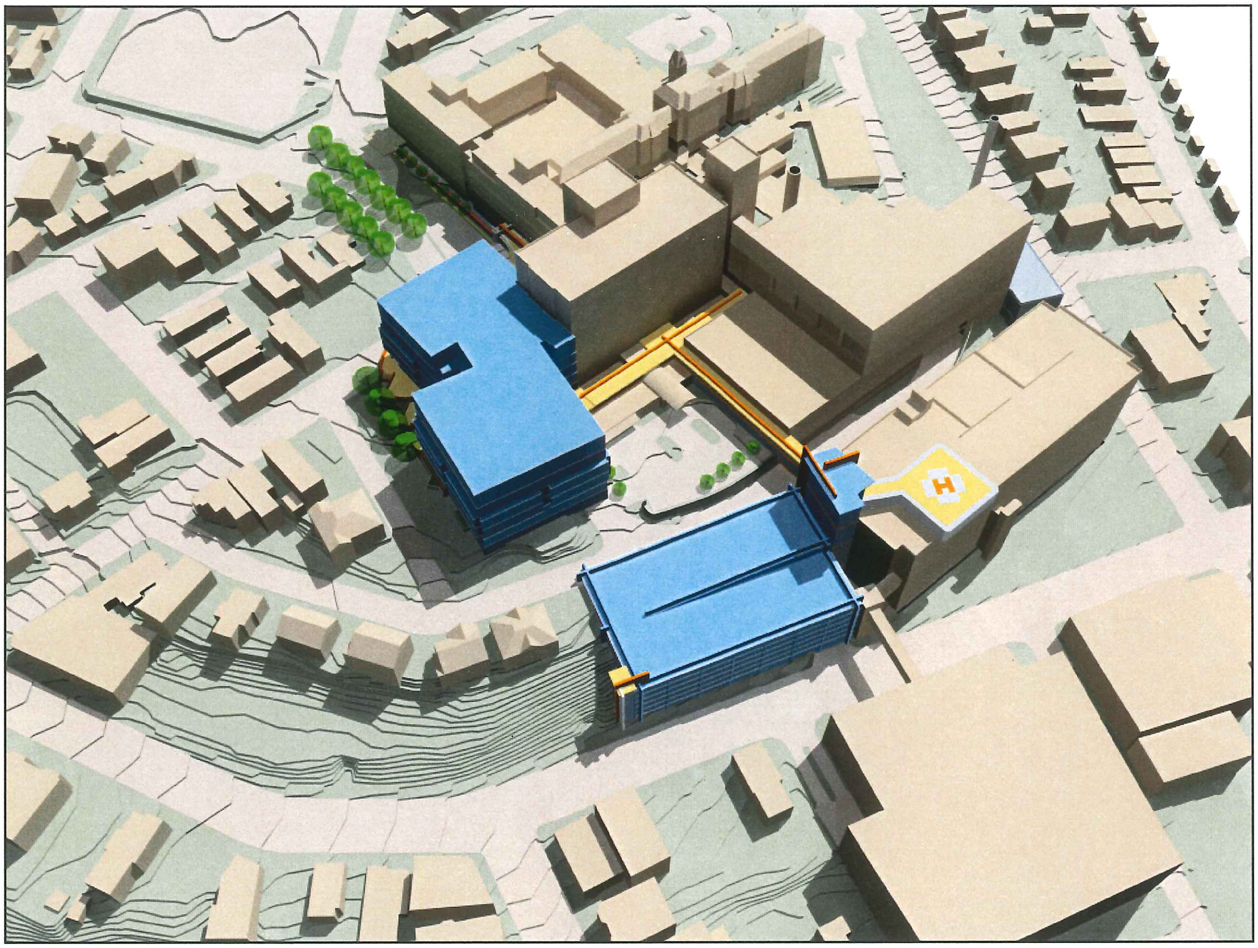
Maine Medical Center
Bramhall Campus



Conditional Zone Agreement
Appendix

Portland City Council
February 2005

Maine Medical Center Bramhall Campus Facility Project
Appendix Table of Contents

Tab 1

Maine Medical Center

Bramhall Campus
Master Facility Plan

May 2004

Maine Medical Center
Mission

The Maine Medical Center is dedicated to maintaining and improving the health of the communities it serves by:

- caring for the community by providing high quality, caring, cost effective health services;
- educating tomorrow's care givers; and
- researching new ways to provide care

Maine Medical Center
Bramhall Campus Overview

- Licensed for 606 acute care beds and 42 newborn bassinets
- Operate and staff 580 beds and 16 newborn bassinets
- 29,400 inpatient admissions; average daily census of 415 patients
- 53,000 emergency room visits; 10,200 inpatient and 7,200 outpatient surgeries; 2,300 deliveries
- Major inpatient services... adult and pediatric intensive care; adult and pediatric routine medical/ surgical care; high risk and routine obstetrics and newborn care; adult psychiatric care
- Full range of diagnostic and treatment services
- Outpatient clinics (medicine, surgery, pediatrics and obstetrics) staffed by MMC faculty physicians, medical students and residents
- Outpatient mental health center

Maine Medical Center
Major Roles

- MMC serves as the tertiary referral center for Maine and the principal provider of hospital services for the residents of greater Portland
- 20% of all admissions to Maine Hospitals are to Maine Medical Center; over 50% of Cumberland County residents' admissions to hospitals are to MMC
- Major specialty services include cardiac, oncology, obstetrics and newborns, trauma, pediatrics, neurosurgery, digestive disorders and respiratory system disorders

Maine Medical Center
Vision for the Bramhall Campus

- Inpatient beds… routine, intermediate and intensive care
- Emergency services and trauma
- Diagnostic and treatment services necessary to support state of the art inpatient services and emergency/trauma services
- Selected ambulatory services supporting MMC's education and training programs
- Medical offices for physicians whose practices are focused on the care of patients at the Bramhall Campus
- Sufficient parking to support patients, visitors and staff

Maine Medical Center
Visions for the Scarborough, Brighton and Falmouth Campuses

- Scarborough… outpatient diagnostic and treatment services, ambulatory surgery, physicians' offices and research
- Brighton… inpatient and outpatient rehabilitation, urgent care and selected outpatient diagnostic and treatment services
- Falmouth… physicians' offices and selected outpatient diagnostic services

MMC Bramhall Campus
Major Buildings and Sites

Building (Date of Construction)	Current Uses
Maine General Building (1870)	support services
McGeachey Hall (1920)	outpatient mental health
Pavilion A (1929)	support services
Pavilions C&D (1956)	ambulatory, inpatient beds, support services
Richards Building (1967)	inpatient beds, diagnostic and treatment, emergency services
Charles Street Building (1970)	support services
Diagnostic Center (1972)	radiology, lab, pharmacy
Engineering Services Building (1979)	support services

MMC Bramhall Campus
Major Buildings and Sites

Building (Date of Construction)	Current Uses
Gilman Street Buildings (1970's)	ambulatory, radiology, support services
Dana Center (1984)	education classrooms and meeting rooms
Congress Street Medical Office Building (1997)	physicians' offices and parking garage
Bean Building (1985/1998)	inpatient beds, intensive care, neonatal unit, labor/delivery, operating rooms, support services
Congress Street Garage	employee and medical staff parking
Vaughn Street Lot	visitor parking

Planning for Hospital Facilities
General Considerations

- Development occurs on an incremental basis... either through re-use of existing facilities or discrete expansion
- Extraordinarily complex and expensive
- Must respond to the rapidly changing health care environment, i.e., advances in medical science and technology
- Requires flexibility and options for development...the world will change again

Planning for the Bramhall Campus
Special Considerations

- Campus topography
- Significant portions of our existing Bramhall facilities are aging and must be replaced
- During the 1990's, MMC development focused on its other campuses... Brighton, Scarborough and Falmouth
- Challenge is to identify short, intermediate and long term needs and proceed with the orderly replacement of facilities

MMC Bramhall Campus
Major Needs

Short Term (3-5 Years)

- Replace labor/delivery and expand obstetrical beds;
- Replace and expand neonatal intensive care beds
- Expand operating room capacity
- Expand number of pediatric and adult intensive care beds
- Expand emergency department capacity
- Upgrade trauma services and add a helipad
- Expand on-site parking

MMC Bramhall Campus
Major Needs

Intermediate Term (5-10 Years)

- Relocate beds from Pavilions C&D to other Bramhall buildings
- Begin decompression of adult routine medical/surgical units in Richards Building
- Respond to advances in medical science and technology

MMC Bramhall Campus
Major Needs

Long Term (10-15 Years)

- Replace the Richards Building inpatient bed capacity
- Respond to advances in medical science and technology
- Major renovation/replacement of Congress Street Parking garage

MMC Bramhall Campus Master Plan Approach

- Three phases… to address short, intermediate and long term needs
- Phase One… identifies specific projects to meet short term (3-5 year) needs
- Phase Two… identifies specific options to begin decompression of the Richards Building medical/ surgical beds
- Phase Three… identifies specific sites to be evaluated in order to proceed with the orderly replacement of the Richards Building inpatient capacity

MMC Bramhall Campus Master Plan
Phase One Specific Projects
(3-5 Year Horizon)

- Charles Street Building for obstetrics and newborns
- Parking Garage adjacent to existing garage with pedestrian connectors to the Bean, Richards and Charles Street Buildings
- Helipad on the existing garage
- Central Utility Plant to serve the Charles Street Building and replace boilers/chillers supporting existing buildings
- Reconfigure main entrances to the hospital
- Widen Gilman Street entrance to the campus to improve access for fire department vehicles
- Re-use Bean 2/Richards 2 vacated by the Charles Street addition
- Expand Emergency Department into basement of Charles Street Building
- Develop an Ambulatory Surgery Center on the Scarborough Campus

MMC Bramhall Campus Master Plan
Phase Two Specific Options
(5-10 Year Horizon)

- Add two floors to the Bean Building for inpatient beds; and/or
- Add two floors to the Charles Street Building for inpatient beds
- Initiate planning for parking garage major renovation/ replacement

MMC Bramhall Campus Master Plan
Phase Three Specific Sites
(10-15 Year Horizon)

- Not likely that Richards Building can be closed, demolished and replaced, i.e., will need to continue to use while replacement is build; same will be true of replacement of Diagnostic Center radiology/imaging
- With what we know today, most likely sites for Richards Building and Diagnostic Center replacement would be:
  - current site of Pavilions C&D
  - current sites of MaineGeneral Building Annexes and Engineering Services Building

MMC Bramhall Campus Master Plan
Other Considerations

In terms of completeness and in response to frequently asked questions about long term development, the Bramhall Campus Master Plan must also address:

- the Vaughan Street parking lot
- the Gilman Street block
- MMC property holdings on the periphery of the Bramhall campus
- neighborhood involvement in MMC planning and development

MMC Bramhall Campus Master Plan
Vaughn Street Parking Lot

- Historically, “mixed” community messages regarding development
- Phase One parking garage will not be operational until 2006; will need at least 3-5 years beyond that (2009) to determine the impact of the new garage on campus parking
- Change in use would eliminate 329 spaces
- As a result, we do not anticipate any change in use of the Vaughn Street Lot

MMC Bramhall Campus Master Plan
Gilman Street Block

- Currently site has three relatively small buildings
- Analysis of alternatives for use of that site have been constrained by the inability to provide parking economically on the site and its location down the hill from the campus
- Expansion of campus parking capacity might make the site more attractive for development… but that is, again a 5-7 year out consideration
- As a result, we do not anticipate any change in use of the Gilman Street Block

MMC Bramhall Campus Master Plan
Property Holdings on the Periphery of the Campus

- MMC owns several properties along Bramhall, Westcott, Brackett and Crescent Streets immediately across the street from the Bramhall Campus; some are used for hospital offices; others remain residential
- During the past 20 years, only two properties (325-327 Brackett Street and the Forest Street Apartments) have been converted to hospital use or demolished… in both circumstances City of Portland Planning Board/Zoning Board approval was obtained; two additional properties will be demolished in the Phase One Project
- We believe it is important for MMC to control these properties on the periphery as a buffer and protection for the campus
- We believe we have demonstrated we are a responsible landlord
- We share the neighborhoods and City's concerns that properties currently used for hospital offices be returned to residential use and will continue to evaluate opportunities to return them to residential use

MMC Bramhall Campus Master Plan
Neighborhood Involvement in MMC Planning and Development

- For the past 5 months, MMC has been involved in an intensive planning effort with representatives of the Western Prom, Parkside and Gilman/Valley neighborhoods
- That effort, supported by a facilitator, has focused on:
  - providing the neighbors with detailed information on the Phase One project and the concepts included in the Master Plan
  - developing a process for ongoing involvement of the neighborhoods in MMC's future planning and development
- A set of "Guiding Principles for Development of the MMC Bramhall Campus" are in the final stages of review. The objective is to ensure neighborhood involvement in the pre-design stages of development

MMC Bramhall Campus Master Plan
Summary Comments

- MMC is committed to the orderly renewal of the Bramhall Campus so that it can achieve the vision for the campus, I.e., the focal point for MMC's inpatient, trauma and emergency services
- Phase One begins that renewal process and addresses some specific needs (parking and trauma/helipad)
- Phase Two focuses on vertical expansion of existing buildings
- Phase Three identifies the preferred sites for major replacement of inpatient and diagnostic/treatment services... these are the preferred sites because of their proximity to existing facilities
- We anticipate no major changes in the use of the Vaughn Street Lot and the Gilman Street Block for 5 to 7 years
- We are developing an ongoing process to ensure neighborhood involvement in the continued refinement and implementation of the MMC Bramhall Campus Master Plan

DRAFT 5/11/04

Guiding Principles for MMC developments at the Bramhall Campus

On the understanding that the MMC Bramhall Campus will continue to evolve and grow over the years beyond the current project, the following are guiding principals for being a good neighbor for this and all appropriate projects. These principles are intended to serve as a measuring stick for all development on the Bramhall Campus and to clarify the neighbors' and MMC's intentions and commitments for all future projects.

Support quality of residential life: Developments will maintain the quality of life for neighboring residents by not creating unacceptable noise, traffic, congestion, pollution, poor design or other negative impact.

Support healthy commercial corridor: Developments will strengthen rather than diminish the viability of the commercial corridor on Congress Street.

No loss of housing stock: Developments will maintain the number of housing units available in the neighborhoods, returning to residential use, where possible, houses which are used for offices

Integrated campus edges: Projects will have campus edges that integrate with the neighborhoods rather than create barriers.

Coordinated pedestrian movement: Developments will invite pedestrian movement to and through the campus coordinating with the City's pedestrian plans and Metro bus stops. Hospital staff and visitors should be encouraged to use the Congress Street commercial area.

Maintain MMC property: The hospital will develop, rehab or maintain the neighborhood property it owns, whether or not the property is part of an immediate project.

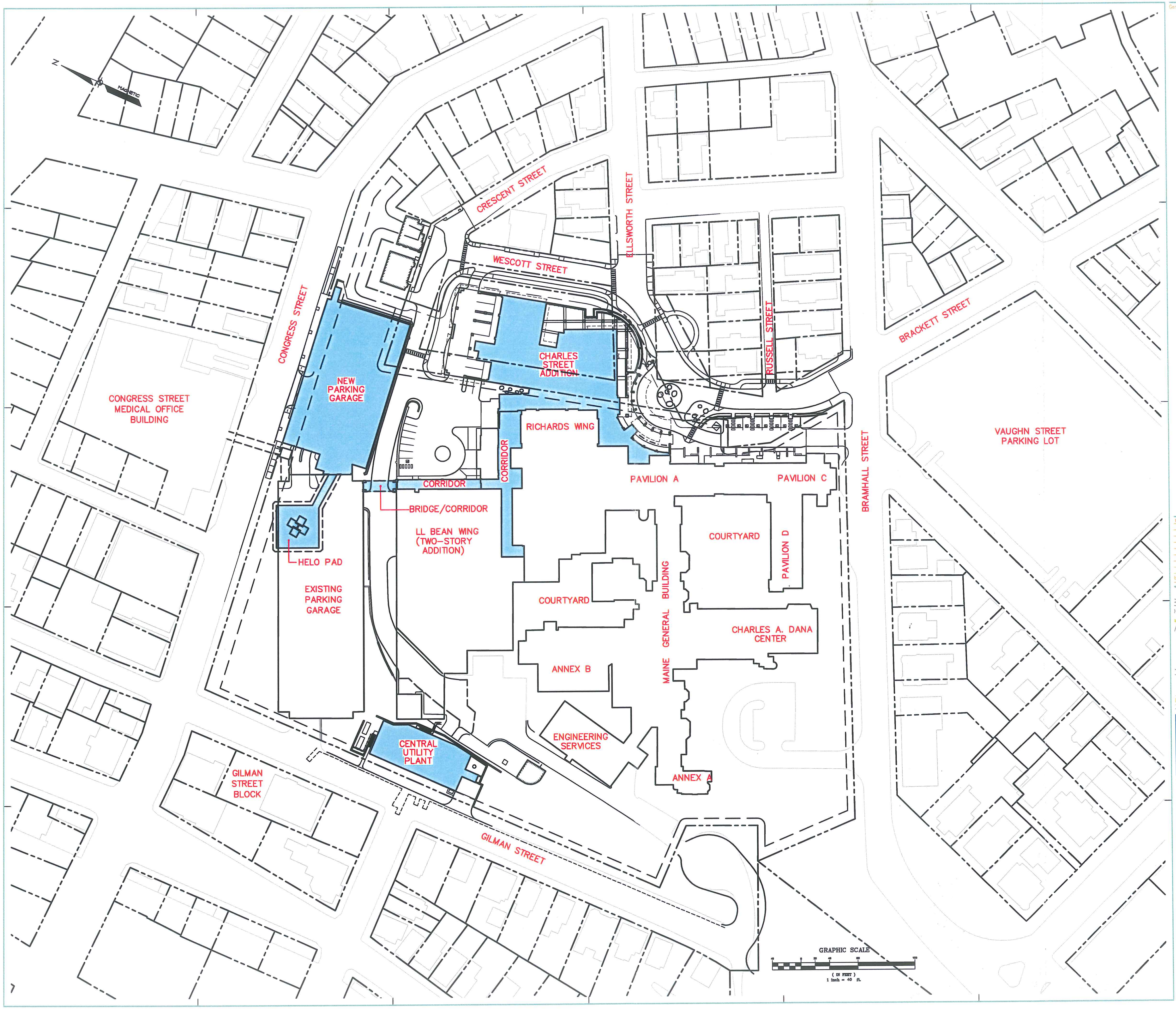
Compliance: All development will be fully compliant with the City's land use policies. zoning and other requirements.

Regular communication: MMC will maintain ongoing communication with the neighborhoods through the MMC Neighborhood Council, which will serve as a place to monitor progress and compliance, field complaints and concerns, provide timely communication between the neighborhoods and the hospital and involve the neighborhoods in the early stages of any future developments. The MMC Neighborhood Council will be notified and engaged when MMC identifies needs for development projects and engaged in the planning.

The MMC Neighborhood Council will be made up of representatives of the Western Prom Association, the Parkside Association and the Valley/Gilman area. City planning staff will be invited to the meetings as well. Other neighborhoods affected by the helicopter flight path will be included for meetings dealing with the helicopter service. Other groups may be added as appropriate.

The MMC Neighborhood Council's work will include:

- The continued development of the Charles Street project, including information sharing regarding construction activities affecting the neighborhoods
- A process to monitor the landing of helicopters at MMC, including a well understood and widely communicated mechanism for neighbors to contact MMC regarding helicopter operations
- Any future development of the MMC Bramhall Campus, ensuring that such discussions occur at the pre-design stage
- Any acquisition of or use of property in the general area of the Bramhall Campus
- Any operational changes at MMC that have the potential to impact the neighborhood

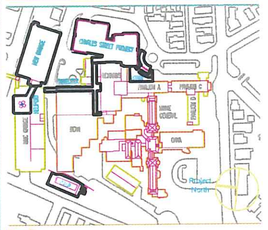


General Notes:

CITY REVIEW

MARK	ISSUE DATE	DESCRIPTION
	1-6-04	FORMAL SUBMISSION

Issue Log



Key Plan

TRO
ARCHITECTURE
PLANNING
ENGINEERING
INTERIOR DESIGN
The Ritchie Organization
80 Bridge Street
Newton, MA 02458-1134
617 969-9400

Maine Medical Center
Bramhall Street Campus
Portland, Maine

Drawing Title
PHASE ONE
DEVELOPMENT PLAN

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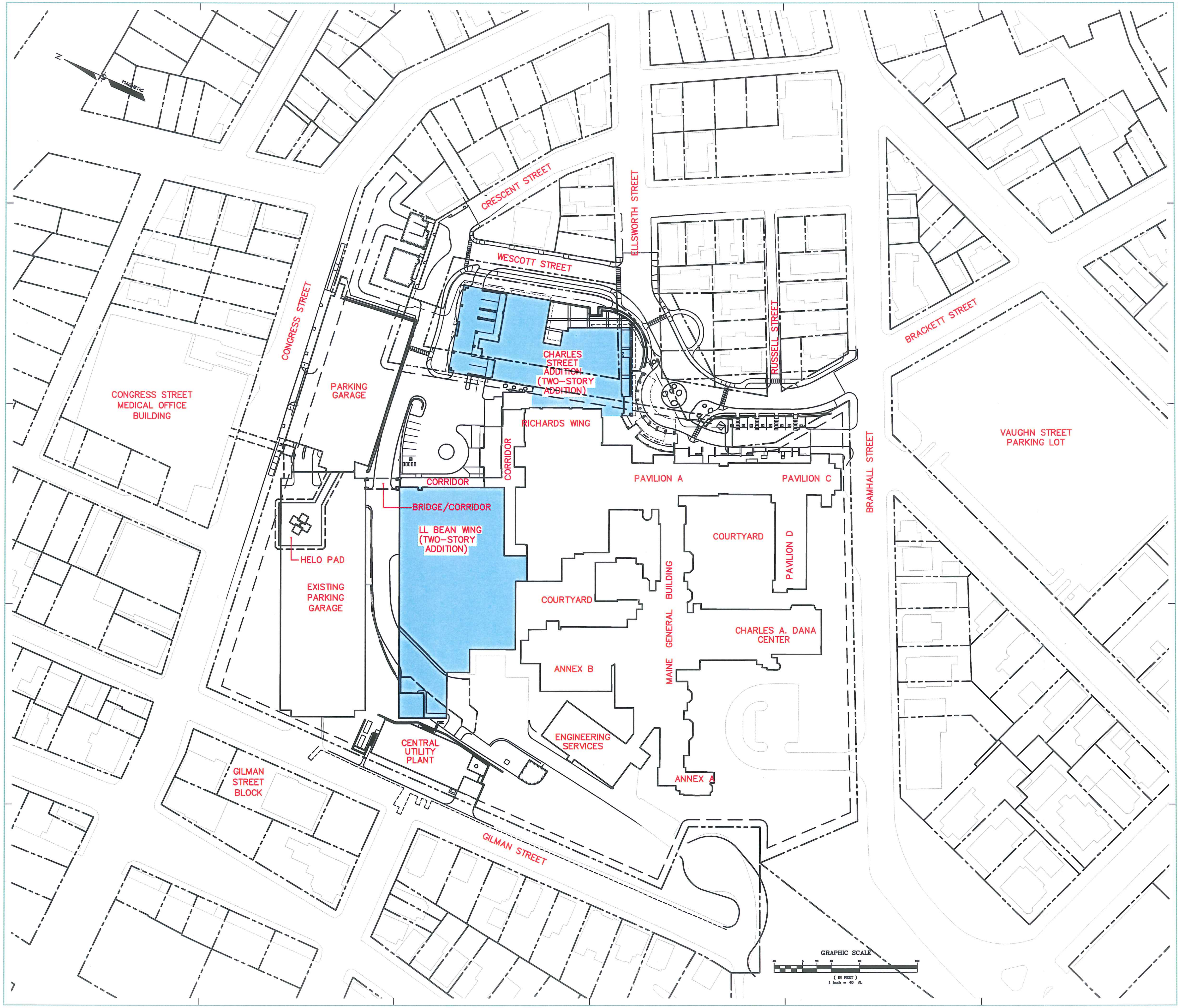

General Notes:

CITY REVIEW

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	1-6-04	FORMAL SUBMISSION

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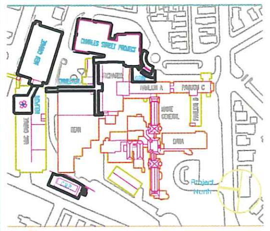

Key Plan

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ARCHITECTURE
PLANNING
ENGINEERING
INTERIOR DESIGN

The Ritchie Organization
80 Bridge Street
Newton, MA 02458-1134
617-969-9400

Maine Medical Center
Bramhall Street Campus
Portland, Maine

Drawing Title
PHASE TWO
DEVELOPMENT PLAN

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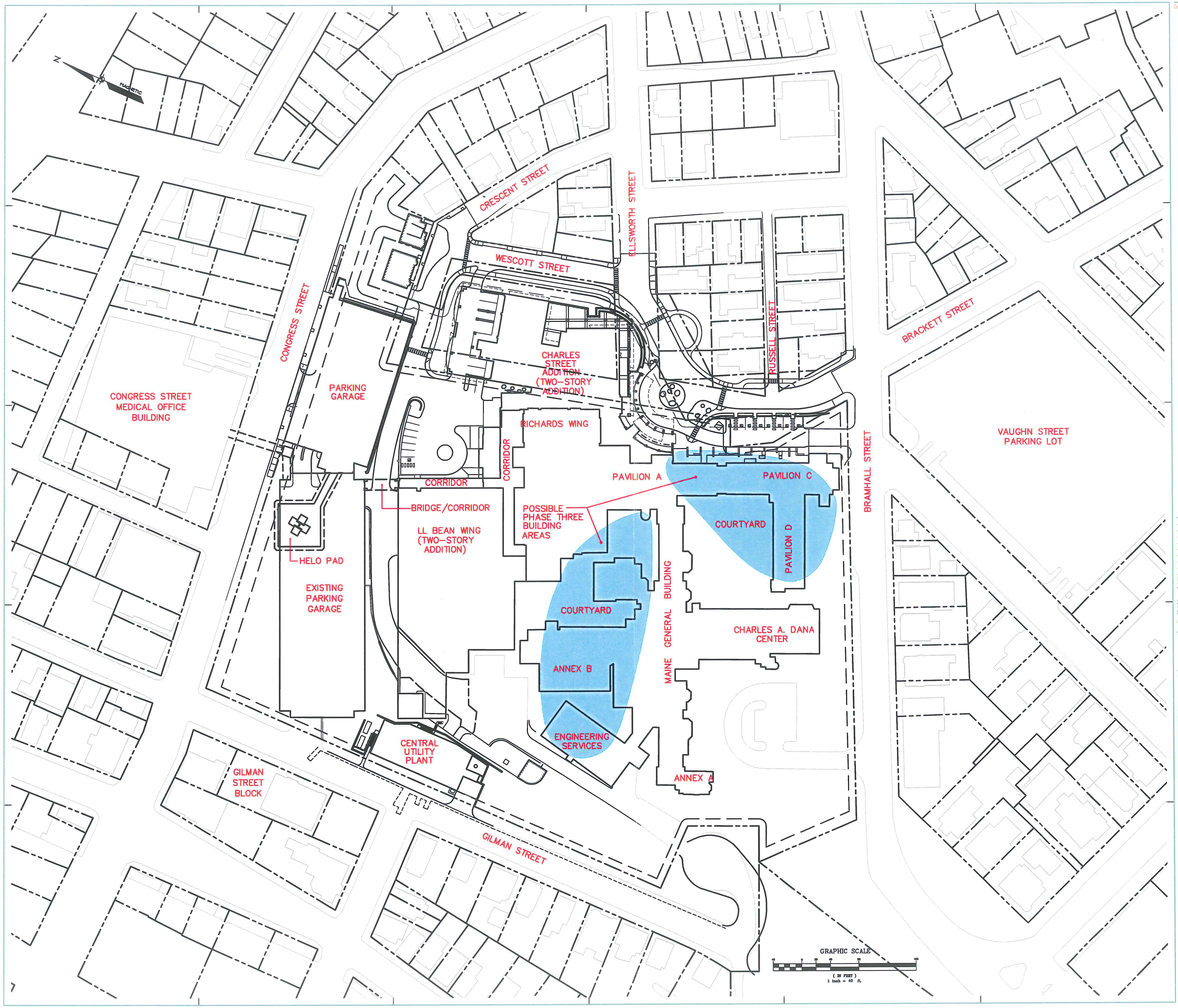

General Notes:

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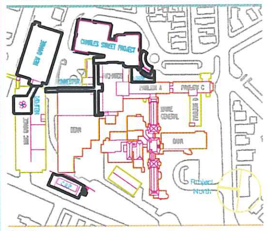

Key Plan

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INTERIOR DESIGN
The Ritchie Organization
80 Bridge Street
Newton, MA 02458-1136
617-969-9400

Maine Medical Center
Bramhall Street Campus
Portland, Maine

Drawing Title
PHASE THREE
DEVELOPMENT PLAN

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Tab 2

Maine Medical Center

MEMORANDUM

TO: Planning Board

FROM: Paul D. Gray
Vice President of Planning

DATE: May 14, 2004

RE: **Conformance of MMC Project with City of Portland's Comprehensive Plan**

In preparing this analysis, we reviewed:

- Portland's Community Vision for the Future
- Portland's Goals and Policies for the Future
- Inventory and Analysis
  - Housing and Population
  - Public Facilities and Services
- Portland's Implementation Plan

The exhibit below compares selected City goals, policies and priorities with MMC's proposed project and our mission, goals and programs. On the basis of that analysis, we respectfully suggest that our proposed project is consistent with the City of Portland's Comprehensive Plan.

Community Vision for Portland
Features to Value, Preserve and Build Upon

	City of Portland	Maine Medical Center
I.	A City That Provides for People	
	• "economic service center for the region" • "regional service institutions which offer high quality medical care"	• MMC is the tertiary health care referral center for Maine and its largest employer with an annual payroll exceeding $215 million. This project significantly upgrades our ability to care for high risk obstetrical patients and sick newborns, trauma patients and adult patients requiring intensive care

22 Bramhall Street, Portland, Maine 04102-3175 (207) 871 [illegible]

The MaineHealth Family

Community Vision for Portland
Future Directions for Portland

	City of Portland	**Maine Medical Center**
I.	Build a Vibrant Small City	
	• "develop new buildings that respect the scale and character of traditional development patterns"	• The Charles Street Building for mothers and babies continues the architectural character established in 1868 with the MaineGeneral Hospital's red brick and limestone. Its design and foot print pull back from the existing structure that will be removed. Landscaping around the campus will be upgraded.
II.	Serve the People	

	• "provide compassionate services for the city's vulnerable citizens, while leading regional approaches to share the responsibility of caring for citizens in need"
	• "expand opportunities, innovative solutions and exemplary services from health care institutions"
		• See the inside front cover for "A Health Place Like No Place in Maine" and "Maine Medical Center and Its Community… Mutual Support, Mutual Benefit"
		• Major community initiatives include:
		  • High risk obstetrics and sick babies
		  • Family Practice Center on Munjoy Hill
		  • Community Mental Health Center
		  • Spring Harbor Psychiatric Hospital
		  • School Health Centers at Portland High Schools
		  • International Clinic
		  • AIDS Consultation Service
		  • Poison Center

Portland's Goals and Policies for the Future

	City of Portland	Maine Medical Center
	Time of Change: Portland Transportation Plan	
	Design Aesthetic (p. 23) - "Build visually attractive and durable infrastructure such as road ways, pathways and bridges"	- Project will significantly improve the Gilman Street entrance to the campus for access by fire department vehicles and create a pedestrian connection between Crescent Street and Congress Street
	Structural System (p. 30) - "Create a neighborhood street system which minimizes through traffic in residential neighborhoods"	- New parking garage's primary entrance on Congress Street will significantly reduce traffic coming up the hill to the Vaughn Street Lot (cars exiting this lot feed into the Western Prom neighborhood)
	Performance Targets and Physical Plan (p. 31) - "promote interconnection of neighborhood streets and pathways"	- Pedestrian connection between Crescent and Congress Streets
	Portland Industry and Commerce Plan Strengthen and Diversify the Economic Base (p. 37) - "create a variety of jobs for full spectrum of the labor pool"	- MMC is Portland's largest employer with an annual payroll exceeding $215 million. This three year construction project exceeds $100 million and will provide job opportunities for all skill levels
	Housing: Sustaining Portland's Future Policy (p. 45) - "While accommodating needed services and facilities, protect the stability of Portland's residential neighborhoods from excessive encroachment by inappropriately scaled and obtrusive commercial, institutional, governmental and other non residential uses"	- Charles Street Building does not encroach into the neighborhood; rather it pulls back from the existing building footprint. Long term development focuses on vertical expansion of existing buildings and new buildings on the current campus - New parking garage sited into the side of the hill on otherwise unusable property eliminates the need to find a site which encroaches excessively into the neighborhood. Does require removal of two houses (currently in very bad condition) which will be replaced.

Portland's Goals and Policies for the Future

	Regulation of Institutional Uses in Residential Zones Goals (p. 48) • "Institutional uses in residential zones should be designated conditional uses" • "any new institutional use should be required to have a lot size of sufficient area to accommodate all activities including parking" • "reasonable expansion of existing institutions should be accommodated, but effective use of existing lot area should be required" • "for new development and expansion of existing institutions, the displacement or conversion of existing dwellings should be avoided and that an institutional development proposal that causes significant residential displacement should be cause for denial of conditional use"	• Planning Board is conducting a full and complete review of this project • By closing Charles Street, the height of the Charles Street Building is reduced significantly. The Central Utility Plan eliminates the need to build at least one additional floor on the Charles Street Building • Housing removed will be replaced • Overall the project makes effective use of existing site (Charles Street lot and sides of hills for Parking Garage and Central Utility Plant) • Long term development focus on vertical expansion of existing buildings and on new structures on the main campus

Housing Population Inventory and Analysis

	City of Portland	Maine Medical Center
	Build a Vibrant Small City	
	• "The City will continue to work on balancing neighborhood stability with the needs of institutions to expand and provide required services" (H-11)	• Project represents a balance of these interests

Portland's Implementation Plan – Major Land Use Initiatives

	City of Portland	Maine Medical Center
	Neighborhood Based Planning Program (p.7)	
	• "Encourage neighborhood with an interest and ability to participate in a planning process and to include a broad cross-section of the community	• MMC has been actively involved in a planning process with its neighbors from the Western Prom, Parkside and Valley/Gilman; guiding principles regarding the development of the MMC Bramhall campus are in the final steps of development

A COMMUNITY VISION FOR PORTLAND

DISTINCTIVE FEATURES OF PORTLAND TO VALUE, PRESERVE & BUILD UPON

Portland is an **intimate city, small in scale but big in urban amenities and a high quality of life**, which is situated around a scenic Maine coastal peninsula. Portland is a city of **neighborhoods around a vibrant downtown,** which make up the building blocks to the community as a whole.

I. A City That Provides For People

- Portland is the largest city in Maine and is the **economic and service center** for the region.
- Portland continues to attract people of workforce age due to **diverse job opportunities** (particularly in business and technology), quality employment, and a stable economy.
- Portland has a **vital working waterfront** with diverse coastal commerce activities and water dependent uses.
- Portland is the center for many **regional service institutions**, which offer high quality medical care, an extensive range of social services for those in need, and numerous higher education opportunities.

II. A City That Is A Good Place To Live

- Portland retains a **small town feel** with a built environment that is scaled for people, is pedestrian friendly, and is accessible to the community. Residents value and seek to enhance the safety of the community, the proximity of commercial uses near residences, and the walkable nature of the city.
- Portland enjoys a personable and congenial atmosphere that makes it **a welcoming place to work, live and visit.**
- Portland offers the **amenities and services** of a big city. Throughout Portland there are diverse arts, cultural and educational offerings, assorted shopping opportunities, numerous scenic parks and active athletic facilities, and high quality municipal services and infrastructure.
- Portland has an **active and vibrant downtown** both day and night due to its interwoven mix of residential, commercial, institutional and cultural land uses.
- Portland is the **visual and performing arts center** of Maine.
- Portland is a **city of neighborhoods** with a range of residential neighborhood types, such as high-density areas on the peninsula, early 20th century neighborhoods off the peninsula, suburban neighborhoods and the more rural areas of the Islands.
- Portland is a great place for families with **good neighborhood schools** that serve families throughout their life cycle.

III. A City That Values Its Natural, Architectural And Cultural Heritage

- Portland is a **coastal community** that is geographically varied and dynamic with:
    - Spectacular views of Casco Bay and the Islands, Back Cove, and Maine's Mountains from the City's promontories; and
    - Three meandering rivers with significant saltwater estuaries and streams that flow through neighborhoods;
    - Significant wildlife and fisheries resources; and
    - Access to our natural features through the City's trails, parks and scenic viewpoints.
- Portland is a **culturally and ethnically diverse community** that values its shared history, is proud of its cultural diversity and is working together for a cohesive community.
- Portland is a **historic maritime city**, which:
    - Retains a rich historic character for both commercial and residential neighborhoods;
    - Offers a broad spectrum of architecture and distinctive landmarks; and
    - Maintains unifying features, such as brick buildings and sidewalks, and established and traditional neighborhoods with narrow and interconnected streets.

A COMMUNITY VISION FOR PORTLAND

FUTURE DIRECTIONS FOR PORTLAND

Portland is Maine's principal city, the **center of employment, housing, and services** for the region. In the future Portland will evolve as an extension, continuation and enhancement of the best qualities and characteristics of Portland today. Progress and prosperity will result from both incremental growth and bold initiatives tempered by careful consideration and foresight in planning. Portland's future will:

I. Build A Vibrant Small City

- Build upon the distinctive fabric of Portland's built environment by **rehabilitating historic resources** and by **developing new buildings that respect the scale and character of traditional development patterns**. New development shall be pedestrian oriented and accessible.
- **Strive for innovation and bold initiatives** that increase the livability and quality of life in Portland.
- Support a **dynamic downtown** that embraces an intertwining of uses, including residential, business, retail, institutional, service, and arts and cultural uses.
- Promote, **support and celebrate the arts and cultural community** that enriches the lives of our citizens.
- **Capitalize on Portland's economic assets** and develop a strong economy based upon traditional industries, a strong retail and office center, and emergent opportunities in industry, business, and coastal commerce.

II. Serve The People

- **Provide compassionate services** for the city's vulnerable citizens, while leading regional approaches to share the responsibility of caring for citizens in need.
- Foster **expanded opportunities, innovative solutions** and **exemplary services** from Portland's institutions for higher education, health care, and community services.
- **Achieve and operate excellent neighborhood schools** with state of the art facilities and which serve the educational needs of all students. Establish wide recognition that Portland schools meet or exceed the educational performance of any other public school system in the region.
- Support and encourage the creation and preservation of an **adequate supply of quality housing** for all.

III. Provide High Quality Leadership

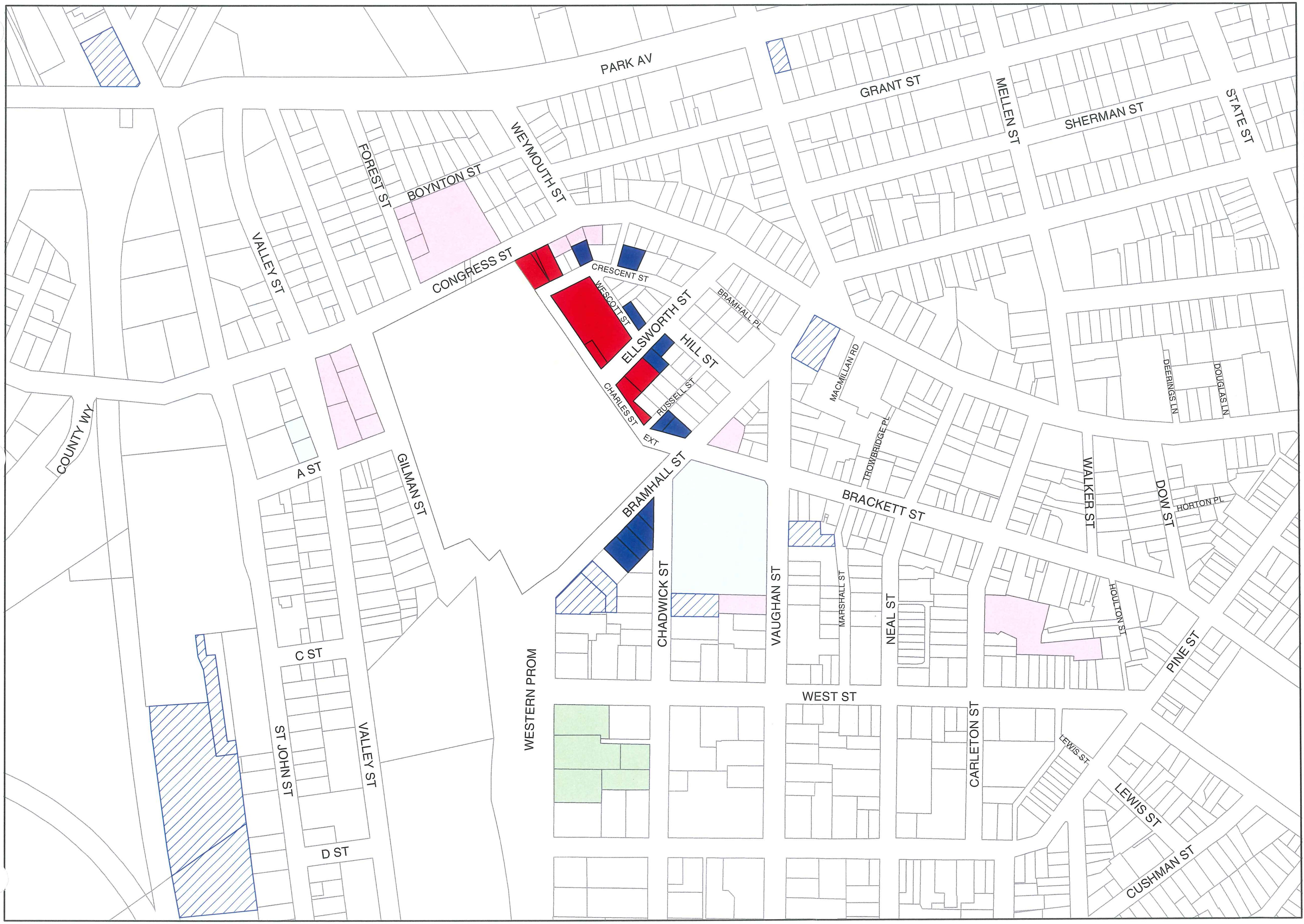
- Create a **sustainable community** with vital neighborhoods, high quality infrastructure, a strong economy, and a healthy environment, while keeping municipal taxes affordable.
- Encourage **excellence in City government and comprehensive planning** through increased civic involvement, responsive local government, accountable decision making, and creative and adaptive local and regional planning. Innovative thinking and leadership will preserve those attributes of Portland that we value.
- **Incorporate environmental, economic and neighborhood considerations** in municipal decision-making.
- Take the lead in developing **clear standards and rules and ensure adherence** thereto.

IV. Protect Our Community Attributes

- **Protect the natural environment** and **historic resources.**
- **Preserve and enhance the park system** with its trails, active recreation facilities and natural areas.
- **Strengthen alternative transportation options** in order to create an accessible City that promotes ease of movement for all citizens, serving neighborhood needs, pedestrians, handicapped persons, bicyclists and vehicles.
- **Listen to, embrace, empower and support our diverse citizenry.**

Tab 3

Locations and Land Use of MMC Holdings in the Vicinity of the MMC Bramhall Campus



Legend

- ☐ Hospital Buildings
- 🟪 Vacant Lot
- 🟪 MMC Offices in Commercial Buildings
- 🟩 Residential
- ☐ Surface Parking
- ▨ Leased by MMC
- 🟥 Required for Project
- 🟦 Planned Divestiture

0 155 310 620 Feet

1 Inch equals 300 Feet

01046 holdings by land use 11x17.mxd
January 10, 2005

Tab 4

Report to the City of Portland:
Helicopter transport into Maine Medical Center

Stephen H. Thomas MD MPH

17 December 2004

Contents

Executive summary

The consultant was charged with assisting the helipad debate by means of assessment and commentary upon the following major points:

1) helicopter triage guidelines currently used to determine who needs air transport by Life Flight of Maine (LFOM) to Maine Medical Center (MMC);
2) clinical and logistic circumstances associated with the current "bifurcated" system (of LFOM transport into Portland Jetport, followed by ground transport to MMC);
3) consideration, based upon review of a series of LFOM-MMC transports, of relative merits of replacing bifurcated transport with transport to an on-site MMC helipad;
4) determination, based upon review of a sample of LFOM transports to MMC, as to the proportion of LFOM patients who could be safely triaged *away* from landing at any on-site MMC helipad, instead using the bifurcated transport model

There were other charges to the consultant. Comment was to be provided on subjects such as mechanisms of benefit associated with use of helicopter Emergency Medical Services (HEMS), clinical and logistical courses of patients in the pre-transport time frame (*i.e.* at trauma scenes or referring hospitals), and helicopter safety concerns. These issues are addressed in the body of the consultant's report, but are excluded from this summary page.

The consultant's work commenced with identification of a study sample of 100 consecutive LFOM-MMC transports. Clinical and logistics information relevant to these patients was obtained by reviewing records at both LFOM and MMC. Data gathering continued with review of LFOM policies and procedures. As needed, the consultant contacted other individuals in the field in order to benefit from their expertise in areas pertinent to bifurcated transport and HEMS safety.

Given the broad scope of the work assigned to the consultant, and the importance of providing supporting evidence for the consultant's statements, this report's conclusions are not easily encapsulated. With the *caveat* that some important details are excluded in a short summary, the consultant's major conclusions comprise the remainder of this one-page abstract.

Most importantly, the consultant concludes that LFOM patients coming into MMC are of notably high acuity, in large part because the currently used triage rules in are reasonable and consistent with national guidelines. There is no reason to suspect there will be major changes in the HEMS triage guidelines, on either the local or national fronts, in the foreseeable future.

The high LFOM acuity contributed heavily to the consultant's opinion that risks associated with Jetport-to-MMC bifurcated transport were concerning. It is left to the City of Portland to adjudicate "acceptable risk." But the consultant's considered decision is that it is highly unlikely there is a prospectively identifiable (*i.e.* at transport time) patient subset of any significant size, in which bifurcated transport could comfortably replace use of an available on-site MMC pad.

Overview of scope of report

As dictated by the City of Portland, with advice from parties interested in the issue at hand, this report addresses multiple facets of the question of helicopter EMS (HEMS) transports into MMC. The main discussions in this report cover:

1) Assessment of the criteria used to determine air vs. ground triage for transports into MMC, with concentration on the questions:
   - Is there consistency between the "local" guidelines (*i.e.*, those dictating HEMS triage for flights into MMC) and generally accepted national guidelines?
   - What is the likelihood that national (and/or local) guidelines will change in such fashion as to lower the threshold for HEMS transports into MMC?
   - Is there currently in place at LFOM, an internal review mechanism for provision of utilization review for helicopter use appropriateness?
2) Review of a consecutive series of HEMS transports into MMC, to:
   - Determine whether air transport triage is being conducted in a manner consistent with the local guidelines;
   - Assess, in a set of actual patient transports, the timing and other process variables associated with the current system of landing at the Jetport and utilizing a ground transport vehicle to MMC; and
   - Adjudicate whether any clinical deterioration (or significant risk thereof) occurred in association with the ground transport leg (from Jetport-to-MMC).
3) Description of consultant-performed "mock run" ground vehicle transports to MMC, as executed from the Jetport and also from the new Mercy Hospital site to the MMC
4) Consideration of safety issues pertinent to the possible on-site location of the MMC pad

The report is divided into sections. The first section following this overview is an introduction to the subject of HEMS and its possible benefits, to both patients and EMS systems.

Introduction and background: HEMS benefits to patients and regions

Air medical transport, as provided by HEMS, has been used in the civilian medical setting since the 1970s. Currently, expert sources estimate that there are 400-450 helicopters providing up to 250,000 transports annually in the U.S.[1] While this report does not intend to focus on the evidence supporting use of helicopter transport in this country, some background information on HEMS and its salutary effects provides a useful framework for the discussion as to the proposed Maine Medical Center (MMC) on-site helipad.

The growth of HEMS has been accompanied by increasing scrutiny as to potential benefits accrued by this resource-intensive intervention. General reviews of the HEMS literature[2-4] have concluded that the weight of evidence supports contentions of outcomes benefits from use of air medical transport. Perhaps more relevant to the situation in Maine and the City of Portland, studies have identified significant mortality reduction associated with HEMS use in nearby urban New England (Boston)[5] and in more distant areas (notably Georgia and Oregon) with more rural demography that approximates the Maine situation.[6,7] Notably, the papers dealing with HEMS and outcomes benefits do not deal solely with trauma. In one study with geographical parallel to the southern Maine setting, HEMS dispatch to non-trauma "stroke scenes" was used in the Florida/Georgia border region to improve patient access to timely provision of advanced stroke care.[8]

When considering whether, and for which patients, HEMS should utilize an on-site hospital helipad, a brief overview of HEMS benefits is helpful. It is important to consider not only benefits to individual patients, but also benefits accrued to the regions served by HEMS.

HEMS benefits to patients

Mortality seems like the most obvious potential patient benefit upon which to focus, and in fact survival improvement has been the main endpoint of most of the major HEMS studies. This is probably because mortality is relatively easy to address in the types of large, retrospective study designs comprising most of the HEMS outcomes literature. Due to the relatively low number of patients for whom HEMS can *definitively* be shown to save lives, studies lacking large numbers tend to have insufficient statistical power to demonstrate a HEMS outcome effect.

Morbidity improvement (*e.g.* better neurological outcome) as a clinical study endpoint has the attraction of being easier to test, since fewer patients must be enrolled to find this more frequent outcome (as compared with mortality). By definition, however, nonmortality HEMS-associated benefits which have been demonstrated – improved pain care,[9] better pediatric[10] and adult[11] endotracheal intubation and airway management, more streamlined access to time-critical cardiac[11] or neurologic[8,13] care – are somewhat less compelling than "saved lives." On the other hand, nonmortality endpoints such as better airway management can provide clues to mechanisms by which HEMS use results in outcomes improvement.

HEMS and regional benefits

Some of the above-mentioned HEMS mortality/morbidity advantages (*e.g.* faster transport of patients with cardiac or trauma to definitive care) have clear relevance to the question of on-site helipad landing at MMC. Also, any intervention that helps individual patients, should also be considered on the positive side of the EMS regional ledger. More specifically to regional issues, there are additional HEMS-associated advantages with particular applicability in areas of Maine-like population density.

As an example of a HEMS advantage with high relevance to southern Maine, HEMS may be the best means for getting advanced-level prehospital care (ALS) to patients in relatively remote regions. On first impression, getting ALS care to patients in remote areas seems to have very little relevance to MMC's helipad, since the issue deals with getting the helicopter and crew to the patient, not getting the patient to the hospital. Upon further consideration, however, there *are* aspects of this regional HEMS benefit with applicability to the MMC helipad question. To wit, patients could incur ALS access delay and outcome detriment, if LFOM is called for initial ALS response and helicopter liftoff is delayed due to getting flight crews back to the Portland Jetport from MMC. Theoretically, LFOM could be delayed in responding, in a manner that would not occur if LFOM were using an on-site MMC helipad, due to crew nonavailability related to their being occupied on the ground leg between the Jetport and MMC. How likely is occurrence of such a scenario? An idea of the relative scarcity – but not absence – of LFOM response delay due to the aircraft/crew being already occupied, can be gleaned from reviewing a set of LFOM transports. For this and for other reasons mentioned elsewhere in this report, a review of records was performed by the consultant. The review entailed detailed reading of both the LFOM and MMC medical records of a consecutive set of 100 LFOM-MMC air transports during a period from 12/2003 through 7/2004.

Based upon the review of records, HEMS delays due to helicopter nonavailability appear to be uncommon in Maine. Nevertheless, when delays have occurred they can be potentially critical. For example, one cardiac patient was to be transported from a community hospital to the MMC cardiac cath lab for emergency coronary care. There was a 37-minute lag between the initial LFOM call and subsequent helicopter dispatch, which was due to the LFOM aircraft being occupied with other transports.

HEMS nonavailability due to having the aircraft and crew busy on other worthy transports can hardly be criticized. Less defensible would be a HEMS response delay due to time lost from having flight crews' needing to make ground transit legs between the MMC and the Portland Jetport. While the scenario of delayed LFOM response, attributable to the ground transport leg and preventable with use of an on-site MMC pad, would not be expected to occur commonly, the example is telling. Importantly, the concepts of regional HEMS benefits, and regional "risks" of HEMS nonavailability for rapid response, illustrate that some risks incurred with the bifurcated transport model are not obvious, and that regional EMS systems considerations should weight in the decision as to whether an on-site MMC helipad is used. Use of a bifurcated transport model not only places the current patient undergoing transport at potential risk, as outlined in some other sections of this report, but there is the additional consideration that the extra transport time can cause risk to *other* patients in the region, who may have urgent need for a helicopter.

Given the time-criticality of many HEMS missions for scene trauma, a ground transport-associated HEMS response delay of even half-hour can have significant effects. As a specific clinical example, airway management serves well. Intubation (placement of a breathing tube in the trachea for ventilatory support) in the field by *ground* ambulance providers has been correlated with *increased* patient mortality, but the same data have demonstrated that airway management by *HEMS* crews – who have higher success rates than ground EMS providers[22] – *decreases* mortality.[23,24] Delays in LFOM response to a trauma scene associated with the air medical crew being "tied up" on Jetport-MMC ground transport, could range from as little as a few minutes to over a half-hour (as might be the case if LFOM is called for a scene transport just after commencing a ground transport leg into MMC). If these delays are of sufficient magnitude that airway management must be deferred for a longer period, or perhaps performed by less well-equipped and less proficient ground EMS providers, there is potential for significant impact due to need for a Jetport-MMC ground transport leg.

There is another system-related benefit to HEMS, which has applicability to the MMC helipad debate. Regionalization of specialty care has improved trauma outcomes, and there is growing confirmation that it improves outcomes in other patients (*e.g.* cardiac, neurologic).[8,12,13] One of the tenets upon which regionalization rests is rapid transport of patients for interventions such as trauma surgery, cardiac catheterization, or stroke treatment. All of these interventions are necessarily time-critical. It follows that a central goal of any medical center striving to provide regionally unique, time-sensitive care, is to streamline the access to that care. It is important to emphasize that this issue is being addressed *not* from any type of marketing perspective (*i.e.* for MMC), but rather from the distinct clinical perspective of having an excellent institution optimize ability to serve its patient population with maximum efficiency and efficacy.

In summing the association between HEMS and individual patient as well as regional care, it is important to keep in mind, that HEMS is intended to transport the most critically ill and injured patients. For others who need MMC care, ground transport will remain the best mechanism for getting to tertiary care. For patients with time-critical need to get to the "referral center," for either diagnostic or therapeutic (or both) reasons, the individual case – and the EMS system and region as a whole – is more likely than not to benefit from elimination of an extra transport leg. The potential advantage of eliminating the Jetport-to-MMC leg is multifold, as will be discussed in subsequent sections of this report.

Subsequent sections of this report address HEMS benefit mechanisms and cover logistics of the MMC bifurcated transport system. The goal is to keep in focus the fact that the best solution to this and other healthcare discussions, is the one that optimizes chances for favorable patient outcome – and by extension improves healthcare for the region as a whole.

HEMS transport speed and out-of-hospital time

When advantages of helicopter transport are considered, one of the first points to arise is the concept of speed. The speed of the helicopter allows the advanced life support crew to arrive at the patient quicker, provides a region with rapid-response advanced care coverage using a limited number of vehicles, and may get the patient to definitive care faster. These are all important advantages that may be accrued with use of HEMS. However, there is more to the "speed" story.

Some of air transport's time-associated benefits, which are due to minimizing out-of-hospital time, are gained even in the absence of HEMS getting the patient to tertiary care faster than ground transport. This aspect of the HEMS advantage to patients has no small relevance to the MMC situation.

In some patients – especially those who are in tenuous condition or who may require difficult interventions in the event of clinical deterioration – the minimization of time spent in the relatively uncontrolled out-of-hospital transport environment is an admirable goal. Expert commentators have long stated that "interhospital transport is not without risk."[28] This section of the report will address some facets of transport risk, and develop the idea that transport should minimize the time spent in the out-of-hospital setting.

It is well known, and consistent with common sense, that a myriad of interventions from airway management[14,15] to advanced life support tasks[16] to chest compressions for CPR,[17,18] are simply more difficult to perform in the out-of-hospital (air or ground) transport vehicle than they are in the controlled setting of the hospital. While transport equipment is of admirable quality, even optimally-functioning prehospital equipment may fail to detect abnormalities (e.g. cardiac dysrhythmias) easily found in the hospital environment.[19] Furthermore, equipment malfunctions seem to occur more frequently in the transport setting; such problems are also more difficult to "fix" outside of the hospital.[19]

To move to specific clinical scenarios, one easily understood situation in which out-of-hospital time is best minimized is the case of a pregnant patient. Given the complicated pregnancies characterizing interhospital transports, and the resultant desire to minimize chances of an out-of-hospital delivery, a rapid helicopter flight is quite preferable to use of a ground vehicle. Since some referring hospitals may have ready access to ground transport vehicles, it is possible that ground transport could be *started* (if not completed) faster than would be achieved with a helicopter. For example, if the helicopter is 20 minutes away, and a ground unit is ready to embark on short notice, it is possible that despite the helicopter's greater speed, the ground transport option would get the patient to the receiving center in a similar time frame. In such cases, helicopter transport could still be preferable; the out-of-hospital time can be relevant even when the overall "transport time" is similar between ground and air transport options.

There were many cases identified in the LFOM-MMC review, in which the minimization of out-of-hospital time was important. A few illustrative examples are informative. One patient, who had respiratory disease, was receiving a certain mode of advanced ventilatory support at the referring hospital. She had to be taken off of this advanced ventilation mode during transport, due to inability to provide the intervention in the out-of-hospital setting; in such a case the absolute minimization of out-of-hospital time was of obvious import.

In another case demonstrating the importance of minimizing out-of-hospital times, a patient had a severe electrolyte abnormality. The patient had the cardiac conduction delays which can be seen with such an problems, and had a pacemaker in place during transport. The transport pacemaker was external transcutaneous device – a type which often fails to capture and control the heartbeat in patients such as the one in question. Failure of the external device to capture requires placement of an internal (transvenous) pacemaker. While a relatively easy job in the hospital setting, internal pacer placement is simply not an option in the field. Thus, it is important to minimize the out-of-hospital time for patients like this one, in whom pacemaker capture failure can translate to the need for CPR.

The intent of this section's discussion is to demonstrate that speed issues are relevant in more ways than the obvious. Even if a patient gets to the hospital in the same amount of time via ground or air transport (*i.e.* if ground transport is able to leave the referring hospital much sooner than HEMS would), in some instances the need for HEMS is driven by the desire to minimize time spent in the less-safe transport setting. Depending on the clinical scenario at hand, the out-of-hospital time issue can have direct relevance to determinations of whether patients should be flown to an on-site helipad at MMC. In trying to ascertain the clinical impact of prolonging out-of-hospital time with a Jetport-to-MMC ground leg, the next step for this report is to characterize the timing of this extra transport leg.

Characterizing the ground transport leg from Jetport to MMC

This section will provide statistical summary of the time incurred by LFOM using the bifurcated system of transport to MMC. For the series of 100 LFOM-MMC transports reviewed, reliable data on the time for the ground leg were available for 36 cases. The mean (average) time was 16.9 minutes (standard deviation, 4.9). The statistical 95% confidence interval for the mean was 15.2 to 18.5 minutes. The median ground leg transport time was 16 minutes (interquartile range, 12.5 to 20.0 minutes); 99% of the ground legs were achieved within the range of 10-30 minutes.

Though there was a lot of missing data, careful review of the applicable information renders highly unlikely any association between presence of transport time data and significantly shorter (or longer) length of ground leg time. In other words, there seems to be no "selection bias" in terms of which ground transport runs had the times recorded. The consultant believes that the time estimate of 15-16 minutes accurately reflects the time required to offload patients at the Jetport and get them to MMC.

Patient transfers during HEMS transport

Apart from the time issues associated with bifurcated transport, another component of risk that must be considered is that which is incurred by the extra physical movement of the patient (*i.e.*, jostling while moving from stretchers to ambulances, and during the ambulance ride). To quantify as much as possible the extent of this potential for patient shifting and movement, the consultant performed a "dry run" from the Jetport to MMC. It was found that the Jetport-to-MMC transit involves a number of steps and two extra patient movements. Considering the high acuity of the LFOM patients comprising the study sample of 100 patients, general use of on-site MMC landings would, in the consultant's opinion, be significantly advantageous as compared to a bifurcated transport model.

The patient transfer issue, taken in consideration with the acuity of the LFOM-MMC cohort, is core to the consultant's judgment that nearly all patients undergoing HEMS transport into MMC would stand to benefit from on-site landing. Development of this theme is the focus of the rest of this section of the report.

A large proportion of patients transported by LFOM have been intubated; that is, they have breathing tube and are undergoing artificial ventilation. In the sample of 100 cases reviewed, 18% of patients were intubated (95% statistical confidence interval: 11% to 26.9%). Intubated patients tend to be of sufficient acuity that they benefit most from expedited transport; for that reason alone these patients should be transported directly to the Level I center (without an extra transport leg) if possible. However, even apart from time considerations, the act of moving intubated patients incurs risk. One complication reported due to moving intubated patients is development of ventilator-associated pneumonia, which appears to be caused by jarring and displacement of ventilator tubes.[27] Furthermore, the fact that patients must often be manually ventilated (*i.e.* "bagged") during transfers entails risk of over- or underventilation and attendant complications. Consistent ventilation synchrony (*i.e.* matching of assisted breaths with patients' spontaneous breathing efforts) is very difficult to maintain during manual ventilation; asynchrony markedly increases the patient's work of breathing.[20] Other problems with manual ventilation include inconsistent positive pressure and potential for worsening blood oxygenation for a given percentage of inspired oxygen.[20] Attendant changes in blood oxygenation are often sufficiently severe to incur substantial risk of low blood pressure, cardiac dysrhythmia, or both.[21]

Other issues may also arise related to ground transport and patient transfers. These risks have been well-delineated in the realm of both intra- and interhospital transport; either setting serves to demonstrate the advantage in minimizing patient transfers. Risks identified in previous clinical studies[29-31] include, but are not limited to: inadvertent discontinuation of blood pressure support drug infusions (with resultant hypotension), loss or infiltration of intravenous lines, repositioning-associated changes in patient comfort (with associated pain-caused physiologic sequelae), accidental dislodgment of endotracheal tubes, displacement of fractures with associated pain and bleeding, movement of surgical drains, and disconnection of cardiac monitoring leads. Furthermore, even in the absence of any dislodgments or equipment-specific issues, it is known that positional changes tend to effect changes in cardiac output and respiratory mechanics.[32] These movement-associated adverse events, clinically significant in terms of both morbidity and mortality,[29] have been shown to occur even when trained personnel are accompanying, and paying close heed to, the patient being transported.[30]

Relevant to the MMC helipad question – which should not be distracted by consideration of rarely occurring risks – are findings that mishaps have been found to occur in as many as a *third* of transports of critically ill patients, and that problems tend to occur during patient movement from one stretcher over to another.[30] Thus, there are clinically important risks associated with even a single unnecessary patient transfer – such as would occur with any ground transport leg after LFOM landing in Portland.

In addition to intubated patients, another population both comprised a large proportion of the LFOM-MMC sample and is also at particular risk from transfers. Pediatric patients, which constituted a fourth of the LFOM-MMC study set of 100 transports, are known to be particularly vulnerable to problems occurring during transfer. This makes common sense to anyone involved with pediatric trauma or critical care, but there is also evidence basis for concerns. Problems with oxygenation and ventilation, as well as inadequate fracture immobilization and resultant displacement and pain, have been noteworthy in studies of pediatric patients.[31]

By this point, the reader could be forgiven for wondering if the risks associated with patient transfer are being a exaggerated for effect. In fact, out-of-hospital care is indeed a potentially dangerous business – especially when the patients undergoing transport are of the acuity found in the LFOM-MMC group. Unfortunately, the risks of moving patients are imperfectly understood even by most healthcare providers. Physicians and others who do not actively participate in day-to-day care of critically ill and injured patients tend to be undereducated as to level of risk associated with patient transfer, even when the transfers" occur within the hospital environment. The sobering truth is that, as one expert reviewer has concluded, at major hospitals about one patient per month suffers cardiac arrest or death from transport-related complications.[33] Thus, patient transport should not be taken lightly, as there are potential risks in just about all who undergo this activity. Selected cases will illustrate the applicability of patient transfer concerns in those individuals being flown into Portland.

There were at least three patients with spine injuries (among other problems). In patients such as these, transport time is a critical parameter of interest for this report. Just as critical, though, is the need for minimization of patient movements, since the "conversion" of spine injuries from incomplete (or even asymptomatic) to devastating is a real risk. The importance of minimizing jostling is also illustrated in the case of a patient who had a rather severe spine injury. The LFOM crew documented their special precautions to prevent further displacement and neurological injury during their transfers of this patient; the success of those precautions does not negate the desirability, in future cases, of minimizing transfers in such patients.

Other instances where the actual movement of patients poses high risk are easy to find in the LFOM-MMC transport series. In patients who have suffered certain types of trauma, the extra two transfers associated with the Jetport-to-MMC ground leg clearly incur nontrivial risk (*i.e.* for further injury, such as the risk associated with transfer of at least one trauma patient in the series of reviewed transports). In another example, a patient who had undergone a temporizing surgical procedure was at risk, due to the potential for complications associated with moving patients who have had such procedures. In these cases, it was important to minimize both out-of-hospital time and also transfers.

Inadvertent traction on both medical and nonmedical instruments and objects is an obvious area of patient transfer risk. There are other instances, less easily explained but nonetheless familiar to prehospital and in-hospital providers, where patient deterioration is associated with the simple act of movement. As an example, one patient suffered a precipitous blood oxygenation drop (pulse oximetry falling to 80% instead of normal >97%) concomitant with movement from the referring hospital stretcher to the LFOM stretcher. No deterioration occurred during the subsequent movements of transferring this patient, but seasoned clinicians would not discount as coincidence the temporal association of transfer and deterioration.

This section of the consultant's report has attempted to portray the only-too-real risks which are incurred by moving critically ill and injured patients from one place to another. Clearly, the transport of such patients to regional facilities such as MMC is, on balance, in the best interests of patient outcome. However, the transport-associated risks outlined in this section should make a case that a plan for getting patients to tertiary care centers, should best incorporate all possible mechanisms to render their movement between facilities as safe as possible. Since the patient sample reviewed for LFOM flights into MMC is of high acuity, this population is a good target for efforts at elimination of unnecessary movements and transfers.

Clinical deteriorations occurring in the 100-transport sample of Jetport-MMC ground legs

Much of the previous sections' discussion has focused on risks, rather than actual untoward clinical events, associated with the Jetport-to-MMC ground transport leg. To some degree, a considered judgment about appropriateness of bifurcated transport should focus on those risks, rather than actual untoward events. This is because the risks, as previously discussed, are based upon clinical knowledge and research; risks and probabilities are more generalizable to future operations than are single occurrences which may never be repeated. Assessment of risks in a large group also avoids some of the subjectivity inherent to retrospective assignment of adverse outcomes. It is not easy to know which patients who did poorly, had suboptimal outcomes due to the extra time or jostling of the ground transport leg. Conversely, no one can, with absolute certainty, aver that any patients who did poorly, did so only because of ground transport.

With the above *caveat*, if analysis of a reasonably large set of LFOM-MMC transports fails to identify any clinical consequences occurring during, or associated with, ground transport, then the likelihood of frequent adverse events from ground transport would seem to be less than that implied by previous sections' discussion. Thus, this section of the consultant's report will address instances in which adverse clinical events – ranging from vomiting to cardiac arrest – happened during the ground transport leg of patient transports between the Jetport and MMC.

One patient had been stable, both neurologically and by vital signs, since before LFOM was called to the referring hospital, where this patient had a neurologic diagnosis. There were no problems during the air transport leg, but during the 20-minute ground transport leg (from 1922 to 1942) the patient suffered significant deterioration (disorientation, speech problems, and lethargy). Upon arriving at MMC, the patient underwent emergency ventriculostomy (to relieve brain pressure) after a computed tomography (CAT) scan.

Another trauma patient, was diagnosed at a community hospital as having both neurologic and spine injuries. He was stable during the air transport leg, but during the ground transport from the Jetport he began yelling and became very agitated (with concomitant increases in intracranial pressure, in addition to potential disruption of his spine injury). Similarly, another trauma patient became very drowsy during the ground transport leg (indicating neurological deterioration, likely from increased intracranial pressure). Increases in intracranial pressure, which are well known to have adverse outcomes in the head-injured patient, also occurred with near-certainty in another trauma patient, who did fine during the air transport leg but who was "bucking the ventilator" (*i.e.* fighting mechanical ventilation) during ground transport.

One trauma patient was noted to have neck vein distension, decreasing breath sounds, and increasing respiratory rate (from 18 to 38 breaths per minute) during the ground transport from the Jetport. These findings strongly suggest collapsed lung. Due to the proximity to MMC when the patient worsened (the ground leg took 12 minutes from 1328 to 1340), no interventions were performed during the ground transport. However, it is clear that had the ground leg been longer, or the LFOM crew more aggressive, the lack of definitive diagnostic interventions – such as X-ray – in the ambulance would have resulted in the patient undergoing temporizing treatment for a collapsed lung (needle thoracostomy). The needle thoracostomy, which involves placement of a needle catheter in the chest to release air from a collapsed lung, would have been painful to the patient and would have necessitated (as do any and all needle thoracostomies) placement of a chest tube. Since this patient was quickly found on chest X-ray at MMC to *not* have the collapsed lung that his clinical signs so strongly suggested, he avoided these procedures. In this case, needle thoracostomy performed during the ground transport *would have been appropriate*, given the clinical circumstances, but it would have translated into a surgical procedure (chest tube placement), significant pain, and many days in the hospital that would have been avoided by having LFOM land on-site at MMC.

In another case, a patient with bleeding did not appear to have significant instability at the referring hospital, but the patient developed low blood pressures during the LFOM air transport leg. The blood pressures stabilized during the air transport leg (there were normotensive blood pressures during final 24 minutes of flight). During the 11-minute interval between the Jetport landing (2159) and loading onto the ground ambulance at 2210 (by which time the patient would likely would have been in or near the operating room given an on-site landing at MMC), the patient rebled and significantly deteriorated such that by 2221 the patient was receiving medications for slow heart rate.

In another case, a patient suffered two logistics-type complications associated with the ground transport leg. First, the battery on the mechanical ventilator became depleted – a complication known to incur substantial clinical risk[19] – and the patient subsequently required manual ventilation. Manual ventilation is less desirable for a number of reasons that are well characterized in the critical care transport literature; these problems have clear applicability to this patient, given her history of severe pulmonary hypertension.[20,21] The second logistics problem in this patient was a delay in the commencement of the ground transport leg. This was due to the need to remix more of the patient's infusion therapy; a remixture which would have been obviated if LFOM had landed on-site at MMC.

The mechanical ventilator battery problem arose again, during the ground transport leg in another patient, resulting in the need for LFOM crew to perform manual (bag-valve) ventilation, with its less effective and more problematic profile (as compared to mechanical ventilation). As an even more concerning problem, the switchover to manual ventilation in this patient – who had suspected sepsis – resulted in unnecessary exposure of the crew to the infectious agent with which this patient ultimately was diagnosed.

In an example of severe, yet unexpected, deterioration occurring during ground transport, a patient who was stable at a referring institution, and had no instability by either complaints or vital signs during air transport. Approximately 11 minutes into a 16-minute ground transport from the Jetport to MMC, the patient's respirations suddenly decreased and the patient became near-comatose; the patient required assisted ventilations during the final minutes of the ground transport and required emergency intubation at MMC. This patient provides evidence of the real-life difficulty of any system which attempts to "triage" patients away from an on-site helipad to bifurcated transport.

As another sample case, a patient had vomiting at the end of the air transport leg. The patient vomited again during the ground transport, with the latest episode of vomiting being bloody. This complication has relevance to bleeding risk during the emergency cardiac cath lab procedure this patient underwent at MMC (since catheterization lab drugs include large doses of potent anti-clotting medication).

Another patient had a decrease in blood pressure just after landing at the Jetport. This patient improved with medications given just after the aircraft landed, but deteriorated after being loaded into the ground ambulance. (If the patient had been landed at an on-site helipad at MMC, the patient would have been in the MMC operating room by the time his condition deteriorated.) This patient's systolic blood pressure dropped to 40 (normal: 120), and by the time the 16-minute ground transport to MMC was completed the patient was in full arrest. This patient's chances of survival were significantly and adversely impacted by the bifurcated transport.

Another patient with a bleeding problem, was receiving a blood transfusion to help balance ongoing hemorrhage. The blood transfusion was completed soon after LFOM landed at the Jetport. During the ground transport leg, which began at 2031, the patient's blood pressure dropped first to 98 (at 2035) and then to a near-arrest level of 55 (at 2040). This patient's vital organ perfusion was clearly compromised at a time when the patient would have been in the operating room if the aircraft had landed at an on-site MMC pad.

Another patient had vomiting during the ground transport leg of the patient's interfacility transfer to MMC's cath lab. This patient had had no nausea or vomiting during air transport. Vomiting is very uncomfortable for the patient, causes anxiety and sympathetic nervous system outflow (not good for patients in the throes of a heart attack), and is associated with the risk of aspiration of gastric contents into the lung. It would appear that avoidance of vomiting may be insufficient reason for triage away from bifurcated transport, but it is not easy to decide in which patients nausea and vomiting risk is "acceptable" if they are of the acuity seen in the reviewed

LFOM-MMC sample.

Another case involved a trauma patient with an unusual piece of equipment in place for transport. There were no problems during the air transport, but a potentially life-threatening problem developed during ground transport. The patient had to undergo a "rescue" procedure in the ambulance during a 13-minute Jetport-to-MMC leg.

In short, this section has outlined clinically significant complications in 14 cases, or 14% of the transports (statistical 95% confidence interval, 8-22%). Importantly, this calculation does *not* include patients with acute illness (*e.g.* heart attack) or injury (*e.g.* brain trauma) for whom prolonged transport associated with the ground leg posed additional risks due to time-criticality of disease (see next section).

Time criticality in the sample set of Jetport-MMC ground transports

Previous sections of this report have addressed overt patient deteriorations occurring during the ground transport leg, and it is the opinion of the consultant that the types of deteriorations that were identified are in the range of "expected" sequelae from bifurcated transport. There is another part of the "deterioration" issue that deserves emphasis, however: patients who are of high illness and acuity simply have better chances at good outcome, if they get to the receiving center more expeditiously. Irrespective of the ability to objectively measure the precise impact of an added 15-20 minutes on patient outcome, the fact is that patients of the nature of those reviewed in the LFOM-MMC cohort are precisely those in whom an extra few minutes can be lifesaving or otherwise critical.

Clinicians have long known that, for trauma, there is an initial period of about an hour (Dr. R. Adams Cowley's so-called "golden hour") during which evaluation and interventions tend to be particularly critical to outcome. Equally certain is the clinical basis for the adage, as applied to patients having heart attacks, that "time is myocardium" (heart muscle). Neurologists providing cutting-edge stroke care have modified the statement to "time is brain." Patients with a variety of other medical conditions, ranging from sepsis to toxicology and overdose situations, stand to benefit from streamlined delivery to tertiary care.

While there can be little argument that patients with acute trauma, heart attacks, strokes, and other obviously time-critical diagnoses should benefit from rapid transport, it is not easy to ascertain any specific adverse events associated with delays incurred by employing a Jetport-to-MMC ground transport leg. There are, to be sure, some instances – which were *not* included in the above sections' outlining of ground transport deterioration events – where ground transport and the attendant delays more likely than not had adverse effects. For example, one patient had worsening of chest pain (due to an acute heart attack) during the final 10 minutes of air transport. Worsening pain directly correlates with dying and "at-risk" (ischemic) heart muscle, so it is obvious that what this patient needed was immediate heart catheterization – which he indeed received, after a delay of 20 minutes incurred for ground transport.

There is no way to know how much more heart muscle was lost due to ground transport time in any given patient, such as any of those urgent cardiac cases (9 in all) involving transport directly to the MMC cardiac catheterization suite. However, as every physician involved with cardiac care knows, a 20-minute delay in getting a patient to the cath lab can have profound impact upon survival and also on non-mortality endpoints (*e.g.* amount of heart muscle lost).

The imprecision of measuring transport- and time-related adverse effects does not mitigate the undesirability of prolonging transport in cases such as that of cardiac patients. Similarly, neither the consultant nor anyone else can say with absolute certainty what extra minutes' ground transport time meant to ICU lengths-of-stay, organ damage complications, neurologic outcomes, or a host of other outcomes endpoints in patients in the LFOM-MMC transport group. However, there is at least one mechanism of focusing the question, and that is to assess patients who received time-critical interventions upon arriving at MMC.

Medical and surgical interventions were often provided immediately upon patient arrival at MMC. Some illustrative cases will clarify the point of time-criticality. One patient had a persistent heart rate above 200 beats per minute, despite about a dozen drug administrations; this patient was successfully converted to a normal heart rhythm by a cardiologist within minutes of MMC arrival. Another patient suffered complete respiratory collapse at the time of arrival at MMC; this patient was immediately intubated for ventilatory support. Another patient underwent an emergency neurosurgical procedure upon MMC arrival. In another case, a patient with a bleeding problem and alteration in the ability to form blood clots (coagulopathy) underwent immediate MMC interventions that included urgent correction of the blood clotting abnormality.

This section has attempted to show that, even in the absence of overt deterioration, patients in the LFOM-MMC cohort tended to have clinical situations in which time was critical. In such patients, lack of deterioration doesn't imply that the patients in question would not have benefited significantly from elimination of the ground transport leg from the Jetport to the MMC facility. The main basis for this opinion of the consultant, and the primary foundation for the consultant's consistent judgment that patients in the LFOM-MMC sample would have been better served by an on-site helipad, lies in patient acuity. The next section of this report addresses the acuity of LFOM transports, with focus on how patients are "selected" for helicopter transport, and on the processes designed to insure appropriateness of helicopter use (utilization review).

Patient acuity, triage, and utilization review at LFOM

One of the charges for the consultant was to assess the HEMS-transported patients for overall acuity, with the goal of determining whether LFOM helicopter triage guidelines were consistent with national guidelines. Additionally, the consultant was asked to comment on the likelihood that there would be national (or local) guidelines changes resulting in significant alterations in air transport utilization. In other words, a question was: How likely is that air medical transports into MMC will increase due to major changes in nationally utilized helicopter use guidelines? This section addresses those issues, and also touches upon the question of whether frequency of HEMS use is likely to increase if an on-site pad is constructed at MMC.

The "national helicopter triage guidelines" used were the most recent, and most evidence-based (*i.e.* founded on the available clinical and scientific research) air transport guidelines available. Published in 2003,[25] these guidelines (which are reproduced in Appendix II of this report) have been endorsed by the National Association of EMS Physicians (NAEMSP), the Air Medical Physician Association (AMPA), and the Association of Air Medical Services (AAMS). The national guidelines were promulgated by the NAEMSP Air Medical Services Committee, and the process of developing and writing the guidelines took the better part of three years. There has been no new evidence widening the scope of air medical transport in the time period since 2003, when the NAEMSP guidelines were published. The consultant can state, to a reasonable degree of certainty, that it is highly unlikely any major changes in the guidelines will occur in the next few years. Major changes after that time period are also unlikely – the literature supporting the first set of guidelines was 20+ years in the making – but any modifications will of course be driven by scientific evidence from clinical studies.

Notably, the consultant was not able, at the time of this report, to collect transport numbers data from a similar area (to Portland) which transitioned from bifurcated transport, to an on-site helipad. One area of potential similarity (Albany Medical Center in New York) was identified, as having transitioned from an off-site to on-site helipad years ago, but that program was not able to provide exact numbers on transport volume. The program's director did indicate that their HEMS service's gradual and modest increase in transport volume did not appear to be affected by the transition from off-site to on-site helipad.[45] In short, the consultant does not believe, based upon his experience with either the triage guidelines or with other programs that utilize on-site pads, that construction of an on-site MMC pad is likely to result in burgeoning numbers of HEMS transports.

The aim of the national triage guidelines is to provide an overview of circumstances in which helicopter use, as compared with ground transportation, is the most appropriate mechanism for getting patients to high-level care. In the case of MMC, ground critical care transport is readily available. The presence of the alternative transport mode means that patients who need to get to MMC, but in whom illness or injury isn't time-critical, can use the ground transport vehicle. The main goal of such ground vehicle utilization is to reserve helicopter assets in order to maximize their availability for truly needy patients. In terms of relevance to the MMC situation, the ground critical care capabilities mean that the average patient who *does* come into MMC by air, is of relatively high acuity.

Contributing to the high relative acuity of air transported patients into MMC is the fact that regional hospitals (*e.g.* Central Maine Medical Center, Eastern Maine Medical Center) serve to "filter out" less critical patients, transferring to MMC (often by air) those patients whose needs outstrip the capabilities of the regional hospitals. As an example of the exception proving the rule, one patient was transported to MMC from a scene after a skiing incident. The patient was initially scheduled to go to another hospital by air, but operating room unavailability at that hospital prompted aircraft diversion to MMC. The point with relevance to the MMC on-site helipad issue, is that patients from further distances (from MMC), whose acuity places them at lower relative risk from birfurcated transport, aren't transported to MMC. Rather, these patients go through a filtering process whereby initial evaluation at referring hospitals receiving the initial air transports (*e.g.* CMMC, EMMC) selects out only the most acute illnesses and injuries for flight into Portland. The end result of this process is that patients transported by air into MMC tend to be, even when compared with other air transports, on the higher end of the acuity scale.

In reviewing the LFOM transports in the set of 100 LFOM-MMC patients, it was clear that LFOM was indeed adhering to its stated triage guidelines, which are represented in Appendix I of this report. Furthermore, the review of details of the LFOM guidelines reveals that they are consistent with the helicopter utilization guidelines promulgated by national authorities.[25] There was no evidence that the LFOM helicopter utilization guidelines were either more or less stringent, than the general accepted parameters for use of helicopter transport.

Reasonable guidelines for LFOM helicopter utilization do not necessarily translate into 100% "appropriate" use. As can be seen, the guidelines are fairly complicated, and it is important to remember that in the state of Maine, helicopter dispatch can be activated by a wide variety of nonmedical personnel (*e.g.* ski area workers, remote woodland corporate entities) that would be expected to be more likely than trained paramedics to "overutilize" the resource. Thus, it is vital that an *a posteriori* "utilization review" occur on an ongoing basis, to insure that the use of the helicopter resource is occurring in a manner consistent with the local (LFOM) and national guidelines.

Upon reviewing LFOM policies and procedures, the consultant has found that there is indeed an ongoing utilization review process. In fact, each flight is reviewed by a physician director and there are feedback loops which help inform and educate referring agencies as appropriate. While an on-site review of LFOM documents was sufficient to convince the consultant of the fact that LFOM post-flight appropriateness review processes were up to national standards, it is more important to note that pertinent LFOM policies have been approved by the national Committee on Accreditation of Medical Transport Systems (CAMTS).

CAMTS accreditation is the highest goal for U.S. air medical transport services, and cannot be achieved unless a given program demonstrates proficiency and efficiency in a wide variety of medical, procedural, and safety parameters; not least among these is the requirement for ongoing utilization review and feedback.[37] As a CAMTS-certified program, LFOM is required to demonstrate that the program follows both the letter and spirit of the rule requiring ongoing utilization review. Specifically, LFOM must perform "a structured, periodic review of transports (to determine transport appropriateness or that the mode of transport enhances medical outcome, safety, or cost-effectiveness over other modes of transport) performed at least semi-annually and resulting in a written report."[37]

During the charges to the consultant, one question that arose was: "Should there be some independent ongoing utilization review of LFOM flights into MMC?" The consultant believes that, *objectively* speaking, the LFOM processes currently in place are sufficient. (This assumes there is ongoing updating and maintenance of LFOM standards to match national guidelines; such would be evidenced by LFOM maintaining its CAMTS accreditation.)

Despite the consultant's belief that adding an additional layer of "independent" utilization review is administratively and medically unnecessary, the Portland helipad debate seems sufficiently vigorous that – in the event an on-site MMC helipad is constructed – some period of ongoing review may be helpful. A truly independent reviewer (assuming one could be easily found and agreed upon) could help assuage fears of inappropriate use of an MMC helipad facility. The arguments *against* institution of such additional review hinge upon both the costs (in time and other resources) of redundant review, and the low likelihood that such a system would identify problems missed by the extant process. The decision is of course left to the City of Portland, but the salient points seem to be: 1) LFOM triage protocols are consistent with national guidelines, 2) LFOM transports as reviewed by the consultant are executed in line with LFOM triage protocols, and 3) there is an appropriate and national-standard quality assurance and utilization review mechanism already in place.

This section has addressed some of the putative explanations for LFOM's high patient acuity, and additionally has made a case that changes in the currently used triage guidelines are likely to be minor in the foreseeable future. Furthermore, it appears unlikely to the consultant that construction of an on-site MMC helipad would add significantly to the current transport volume profile of LFOM into MMC. The next sections address what actually appears to happen, during a "mock transport" from various locations to the MMC.

Mock transports

The mock transports were executed so that the consultant could get a first-hand sense of what was entailed in the various possibilities for getting air-transported patients into MMC. They are necessarily subjective, with some estimates of time that may not be precise, but the general information obtained was of substantial value to the consultant, and may be illuminating to the reader of this report.

Mock transport from Jetport to MMC

To familiarize the consultant with the current logistics of the ground transport leg, a "mock run" from the Portland Jetport to the MMC was executed at approximately 1500 on a weekday (11/18). This time was selected because it correlated with the time that appeared to correlate with the highest volume of LFOM-MMC transports.

Upon landing at the Jetport, the helicopter waits 2-3 minutes for the engines to "spool down." LFOM does not engage in hot-offloading, which is the practice of removing the patient to a ground ambulance while the rotor blades are still turning. Hot-offloading of patients is uncommonly indicated, and incurs a greater risk to ground personnel than does the alternative of "cold-offloading" (after the rotors have stopped turning). Conversations with LFOM personnel indicate that hot-offloading is "not an option" with Jetport transports, due to its being disallowed by the personnel (Medcu) providing ground transport. For the vast majority of cases, landing of LFOM at an on-site MMC pad will not save the few minutes required by the practice of cold-offloading; however, it is conceivable that with appropriate training the use of an on-site MMC pad can offer the *potential* to utilize hot-offloading in highly time-critical cases.

Subsequent to patient unloading from the helicopter, the patient is placed onto a transport stretcher, rolled to the ambulance, and loaded into the ground vehicle. In combination with the subsequent need for post-ground leg transfer to the hospital stretcher, the current ground transport system thus entails *two* patient transfers: one to the ground ambulance, and another to the hospital stretcher at MMC. (This compares unfavorably to the on-site MMC pad system's single transfer onto a hospital stretcher from the rooftop pad.)

After the patient is loaded into the ground transfer ambulance, the ground vehicle must leave the security-controlled area of the airport. This step, which requires an attendant to open a locked gate, usually takes negligible time. However, LFOM crew indicate that on occasion, there is a wait to get the gate opened. For example, in one patient with severe bleeding, there was an 8-minute time lapse between Jetport landing and commencement of ground transport to MMC. The LFOM record notes that 6 minutes were required to get the patient into the ground ambulance, and a 2-minute delay was incurred to "get going" (which was later translated by LFOM personnel as indicating problems getting through the gate).

After the ground ambulance clears the security zone of the Jetport, there is a turn onto the road towards MMC. This turn, by the consultant's count, is the first of *nine* 90-degree turns that the ground ambulance makes during its journey to MMC. Depending on the clinical situation, these turns and the associated patient movement risk can pose as much, or even more, patient safety (and discomfort from pain or nausea) concern as the actual time required for the ground transport leg. The MMC drive also entails passage through many traffic lights (twelve, by the consultant's rough count) and a stop sign. Even if these "obstacles" do not force stoppage of the ambulance, there is an expected change in smoothness of transport vehicle's transit which can pose additional issues ranging from nausea to vehicle motion-related technical problems.

During the consultant's "dry run," the time elapsed between departing the Jetport and arriving at MMC was 15 minutes. Since this 15 minutes was driving time only, and didn't take into account the time (usually about 3-5 minutes) required for patient offloading from the helicopter and loading into the ambulance, this time is shorter than that calculated from the available records from LFOM-MMC (see section on ground transport times). Given the fact that the time (as compared with the consultant's timing run) "lost" by transferring the patient is "gained" by Medcu running with lights and sirens to MMC, the consultant's calculated time of 15 minutes is consistent with what would be predicted based upon the available information.

Mock transport from Mercy (new site)

To familiarize the consultant with the potential logistics of a ground transport leg from the new Mercy Hospital site (near the river, on the same side of the railroad tracks as is MMC), a "mock run" from the site to the MMC was executed at approximately 1300 on a weekday (11/20). Upon landing at the Mercy site, the helicopter waits 2-3 minutes for the engines to "spool down." It is not anticipated that the option of "hot-offloading" would be a possibility at a non-MMC facility, but this cannot be ascertained without doubt. Subsequent to patient unloading from the helicopter, the patient is placed onto a transport stretcher, rolled to the ambulance, and loaded into the ground vehicle. Notably, the use of the ground ambulance, instead of a (MMC) hospital stretcher, to receive the patient from the helicopter results in the same two-transfer need that the Jetport bifurcated system entails.

After the patient is loaded into the ground transfer ambulance, the ground vehicle departs for MMC (without any potential delays due to airport-related security gates). After the ground ambulance turns left (during the consultant's mock run, from a driveway near Redlon & Johnson company, onto St. John street), there is a short drive to Congress street. At Congress, the ground vehicle will turn right and continue on to MMC.

The mock run from the proposed Mercy site entailed five 90-degree turns. Two traffic lights were in the pathway. Having been calculated in a run in which the traffic lights were green, the consultant's estimated "new Mercy"-to-MMC transit of about 3 minutes probably approximates fairly closely, the "real-life" transport time between those two sites. To this three minutes should be added the expected time for engine spool-down and patient transfer to the ambulance, to achieve an expected total time (from helicopter landing to patient arrival at MMC) of about 8-9 minutes.

Mock transport from proposed rooftop helipad

The aircraft will land on the rooftop of a parking garage. Subsequent to patient unloading from the helicopter (see discussion above, covering hot- vs. cold-offloads), the patient is placed onto a rolling hospital stretcher (important: a single patient transfer rather than two). An elevator (dedicated to LFOM use when the aircraft arrives) will take the patient down about 20 feet (2 levels of the parking garage), after which time the patient must traverse a distance of about 100 feet (over a street). This is achieved in a closed and air-conditioned/heated hallway, after which a right turn brings the patient to the operating suite, or a left turn brings the patient into the Emergency Department. There is a dedicated CT scanner in the ED (which has relevance to certain types of emergent cases such as strokes).

Since the helipad and related structures are not built, times estimated for this transport system are estimated. Assuming a cold-offload and a ready elevator, it would appear that the total time elapsed between landing and patient arrival in the E.D. (or OR), would tend toward 4-5 minutes. Perhaps more importantly, at least for the sake of comparison against logistics setups involving ground ambulance legs, elapsed times could be assessed as the interval commencing with patient loading onto the first stretcher (transport stretcher for ground ambulances, hospital stretcher for on-site MMC transports) after helicopter landing. By this adjudication, the patient could be in the MMC ED/OR within 1-2 minutes after being offloaded from the aircraft.

Use of an acuity or time-of-day dependent helipad triage system

The crux of the issue confronting the City of Portland appears *not* to be whether an on-site MMC pad would be good for some patients, but instead whether such a landing area would be necessary for *all* patients. The current system uses a bifurcated approach, in which patients land at the Portland Jetport and subsequently undergo an additional trip in a ground vehicle. The issue of risks (from transfers and from time costs) associated with this extra transport leg have been outlined elsewhere in this report. It is not the intent of this section to reiterate arguments and impressions noted elsewhere. Rather, this section assumes that direct-to-MMC (on-site pad) transport *is* available and agreed-upon to be preferable for many HEMS patients; the section's goal is to consider whether bifurcated transport (*i.e.* as occurs now) should be maintained as an option for *some* patients (as defined by acuity or time-of-day).

One point to make is the that construction of an on-site MMC helipad would not, irregardless of any triage rules, completely eliminate the possibility of Jetport-MMC bifurcated transport. This is because weather considerations could occur, which would exclude flight into MMC but which would allow transport into the Jetport due to the latter's navigational advantages as an airport. This situation is not anticipated to occur commonly, but it is worth mentioning in any discussion about whether bifurcated transport should be "discontinued." The rarity of weather-dictated bifurcated transport is well-predicted, based upon the experience of other HEMS programs in New England: the fact of the matter is that when the weather is truly bad, no HEMS operations will occur (to the Jetport or to MMC).

If the system of bifurcated transport works now, and if it must be available for the rare case where weather allows helicopter operations but closes the MMC helipad, then why not have an approach whereby pre-flight screening determines the appropriate landing area? Such a triage system would, for example, come into play for nighttime operations where noise would be a particular consideration. For cases of lesser acuity, where there is lesser risk from patient transfers and time delays, it seems quite fair to pose the question as to why on-site MMC landing is really necessary.

If there is a helipad on-site at MMC, there would be only two reasons to triage patients away from landing at MMC and incur the extra resource expenditure and patient risks associated with use of the ground transport leg. These two reasons are safety and noise.

The issue of noise is addressed by another consultant's report. The issue of safety is covered in another section of this report, but some safety notes may be relevant here. If the weather is particularly bad, it may be safer to land aircraft at the Jetport, as noted above. Pilots routinely make this type of decision, and the certification of LFOM (which provides nearly all helicopter transports to MMC) by the Committee on Accreditation of Medical Transport Systems (CAMTS) demonstrates that program's demonstrated excellence in, and commitment to, safety issues which include pilot qualifications and training. Thus, for instances in which bifurcated transport is necessitated by weather/safety considerations, it is reasonable to believe that HEMS programs and pilots will exercise appropriate judgment. Other, closely related, safety-related information is found separately in this report in a subsequent section.

The critical reader may have noted the phrase, used on the previous page, "If the system of bifurcated transport works now." A rational philosophical objection to construction of a new helipad is: "If all patients currently go into the Jetport, do we *really* need to re-triage *all* patients to an on-site helipad?" In other words, where are all of the adverse medical outcomes ascribed to the ground transport leg?

As outlined in another section of this report, there *are* many adverse medical outcomes that have been associated with the ground transport leg. Rather than repeating clinical information previously iterated, the consultant will refer the reader to this report's sections discussing risks and deteriorations associated with the ground transport leg. The point is, the system "works" now, but it could clearly work better, for nearly all patients. The mere fact that a certain approach may be the best *current* solution does not translate to any certainty that there is not room for significant improvement.

Given the critical reminder that the opinion is based upon the consultant's review of LFOM-MMC transports revealing a clear pattern of high acuity, it is the consultant's judgment that transition to an on-site MMC helipad will effect substantial improvements to a system which is already good. As the major trauma center for Maine, MMC would do well to improve system care by offering the same expedited helicopter access as that which is now available at many other state facilities such as Eastern Maine Medical Center and Central Maine Medical Center. Given the high acuity of the trauma patients in the 100-patient sample, the consultant believes that transporting a trauma patient to the Jetport, if an on-site MMC pad were available, would not meet the standard of trauma care. Similarly, in virtually all cases of "scene" transport, trauma or otherwise, landing at an on-site MMC pad would be dictated both for considerations of trauma care, and due to the inevitable uncertainty underlying clinical knowledge about patients who haven't yet been evaluated by a physician.

If the idea of triaging trauma and scene patients away from an on-site pad isn't viable, the next step is to consider directing other (no trauma) patients away from rooftop. In this case also, the strong argument to maximize use of the on-site pad is based upon the imperfections of triage – imperfections that are not likely to go away any time soon. While a *retrospective* review can identify cases in which no adverse events occurred during ground transport, it is virtually impossible to predict, in a patient sample of the marked acuity of the LFOM-MMC cohort, which patients will be the unlucky ones. In some cases – trauma patients, those with ongoing chest pain from heart attacks – it is theoretically easy for a bifurcated system to triage the patient to the on-site hospital landing pad. Complications arise when it comes time to draw the line, and to determine which patients are "well enough" to *not* be at risk from the ground transport. (This doesn't even begin to consider the fact that provision of an infrequently utilized intervention – in this case ground transport – is associated with deterioration of the skills and expertise required to optimally perform that intervention.)

At the heart of the matter is the fact that for patients who aren't in obvious need of an on-site helipad, there is no triage mechanism possessing sufficient safety margin, that can be used to allow confident direction of the patient to the option of prolonged ground transport. The triage officer must have accurate information upon which to base a decision. However, any clinician who works in a tertiary hospital, and who has accepted patients in transfer, knows that – despite the best interests of community hospital providers – the patient that arrives at the Level I center may not bear much resemblance to the one described in the transfer conversation. This is not meant as an indictment on providers at referring hospitals, since patient situations change and diagnosis is still an inexact science. However, the relevance to the MMC helipad debate remains: regardless of the underlying explanation, any information given to a triage officer who is trying to figure which patients can go to the Jetport, should be viewed with healthy skepticism. For example, in a patient for whom LFOM transport was requested due to suspicion of a problem in the (noncerebral) vasculature, MMC specialists quickly realized the vascular problem had nothing to do the patient's problems; instead the patient was determined to have a stroke.

There is more to the triage difficulty argument than anecdotal stories (such as that of any of the previously mentioned LFOM-MMC patients) and the consultant's extensive experiences of patients arriving at tertiary care in quite different shape than that billed by transporting facilities. Clinical research demonstrates that patients undergoing interfacility transfer are inherently hard to characterize, and that they often are "sicker" than commonly used objective scores can measure.[35] The relevance to the MMC situation is: patients who appear to be "well enough" for bifurcated transfer may in fact have some of the other, more difficult to assess, characteristics associated with higher risk during transport. In a patient population in whom the acuity levels are low- or mid-range, the risks of triaging away from an on-site MMC pad are likely at a comfortable level. For the patients in the LFOM-MMC cohort, however, illness and injury acuity are sufficiently high that a reasonable and objective triage officer would rarely choose to incur the risks attendant to ground transport, when an on-site landing area is readily available. For example, to recall a previously noted case: patients can be stable in the ICU without any kind of deterioration occurring during air transport, but then, during the Jetport-to-MMC leg, they can suddenly become near-comatose with severe respiratory depression. This was a stable patient at another institution, who had passed the "test of time," for whom a "triage officer" could quite reasonably – and wrongly – denied access to an on-site MMC pad.

Since a system whereby triage to bifurcated transport is based upon injury acuity or other factors (such as time of day) appears less desirable than direct-to-hospital helicopter routing, the question arises as to whether such systems currently exist. The consultant being unaware of any such systems in the U.S., others with expertise were asked about whether they were familiar with a logistical model of the triage-to-bifurcated transport type.

HEMS services in the U.S. tend to be run by vendors that supply pilots and equipment to hospitals and other agencies running the HEMS service; the vendors bring aviation expertise to the partnership whereas the hospital personnel bring medical and transport expertise. The consultant contacted representatives from HEMS vendors, asking whether they were aware of any system whereby patients are triaged away from on-site helipads depending on clinical acuity or time of day.

The Director of Operations at one of the largest and oldest vendors, Keystone Flight Services which operates 35 helicopters flying from 28 locations in the U.S. Northeast, responded: "There are no Keystone contracts that I am aware of who have night restrictions on hospitals. This includes the receiving hospital helipads as well as the hospital helipads they take patients from."[38] The Vice President and General Manager of Keystone's Flight Services added: "To my knowledge we do not operate from any hospital heliports that are restricted from use at night."[39] Another vendor widely used in the U.S. is CJ Systems Aviation Group, which manages air medical services of 105 helicopters at 77 base sites. Their Director of Operations reported that: "I have not seen such a restriction in any of the programs we support."[40] Additionally, the Executive Director of the Association of Air Medical Services, to which organization nearly all American HEMS operators belong, answered: "I have not heard of any heliports operating under this kind of split/differentiated schedule."[41]

The consultant has been involved, to some degree, in situations at two locations in which the issue of bifurcated transport may be applicable. In the City of San Francisco, a helipad serving San Francisco General Hospital has been and remains the subject of intense debate, which involves a variety of issues including environmental impact, noise, safety, and even impact on overcrowded hospitals in the San Francisco area. (The consultant was involved in the process, to the extent of being asked to comment on medical importance of having an on-site helipad for a Level I Trauma Center.) While there are neighbors involved in the helipad process, with final hearings still pending, the Department of Public Health EMS authorities in San Francisco have "never considered a 'bifurcated' approach to landings." [44]

In another major city, much closer to Portland, a sort of bifurcated transport does exist, but the situation in New York City (specifically, Manhattan) offers few parallels to a plan for acuity- or time-of-day based triage of MMC patients away from an on-site helipad. First, and maybe most importantly, the issue in NYC is that helicopters – of *all* types, EMS and other – are not allowed to land on pads in Manhattan. This decision, which appears to be the result of a 1997 crash into the East River, of a Colgate-Palmolive corporate helicopter, is not likely to be modified given the occurrences of 9/11/01. The consultant, having served two visiting professorships in NYC, is familiar with some of the relevant issues. Of significance is the fact that in NYC, the helicopter "ban" applies only in Manhattan; a plentitude of Level I trauma centers in surrounding boroughs (and in New Jersey) translates into a rare need for HEMS transport directly into Manhattan island. Furthermore, there are no systems in place – to the knowledge of the consultant, or to others with experience with HEMS transport in New England and New York City,[42] – for differential triage to bifurcated versus on-site transport in NYC; indeed, the experts with whom the consultant spoke were of the impression that outside of rare/emergency contingency plans for landing in Central Park, there was *no* provision for HEMS to land at hospital sites in Manhattan.

Helipad sharing

The consultant was to report on any issues related to a system of helipad sharing, between MMC and Mercy Hospital. There is a new building site to which Mercy Hospital is relocating, and it is the consultant's understanding that Mercy has approval to construct an on-site helipad at their new location. The question which has been posed by participants in the MMC helipad debate is: Do we really need two helipads so close together?

If the patients comprising the LFOM-MMC transports were of lower acuity, then there could perhaps be reasonable argument in favor of a "shared helipad" system whereby MMC-bound patients land at Mercy and then undergo a relatively quick ground transport leg to MMC. With the acuity characterizing the LFOM study sample, however, the patient transfer issues mentioned elsewhere in this report come into play, even over a short-distance ground leg.

Given the axiom that *processes* (*e.g.* patient transfers) inherent to performance of a ground transport leg can represent as much of a threat to patients as do time delays, the consultant's judgment is that a shared Mercy helipad is not a good answer to get patients to MMC. Speaking from the perspective of medical appropriateness, it seems clear to the consultant that the overwhelming preponderance of patients, including all adult and pediatric trauma patients, would be using the shared helipad as a means to get to MMC – not Mercy. Considering the transport-associated risks as outlined elsewhere in this report, medical needs and risk assessments render untenable a "solution" in which the Jetport landing plan is exchanged for a plan to land in-town, at a non-trauma center hospital which by any calculation would receive a distinct minority of air medical transports. The consultant has not performed any clinical reviews of patients going to Mercy (though the facility seems to not receive HEMS transports on any regular basis), so the possibility of a shared helipad *at MMC*, with occasional transports of patients down the hill to Mercy, may indeed be feasible.

Safety considerations

As mentioned earlier in this report, safety is one of the theoretical foundations upon which to base concerns about an on-site MMC helipad. As noted, the particular safety profile of *current* HEMS operations in Maine (with LFOM expected to provide nearly all air transports into MMC's pad) is such that in the consultant's opinion, it is fair to assume that any HEMS helicopter landing at MMC's on-site pad, is maintained and piloted at the top of industry standards.

Before discussing just what the industry standards mean, it is worthwhile to digress and discuss what happens when a program operates *outside* the standards. Unfortunately, the people of Maine are only too aware of the risks. From the National Transportation Safety Board (NTSB) report BFO94FA013[36]:

> "On November 19, 1993, at 2039 Eastern Standard Time, a Bell 206-L-1, N911ME, landed hard during a forced landing touchdown in the Atlantic Ocean seven miles east of Portland International Jetport, Portland, Maine. The helicopter was owned by Airmed Skycare Inc of Portland, and operated by Echo Helicopter Inc. of Portland, Maine. Instrument meteorological conditions prevailed at the accident site. The certificated commercial pilot received serious injuries, while two of the three passengers were fatally injured. The third passenger has not been recovered and is presumed to be fatally injured. The helicopter was submerged in 85 feet of water and was destroyed. The flight was conducted under part 14 CFR 135. The medical evacuation flight originated in Ellsworth, Maine."

The NTSB report narrative continues on, to outline tragic consequences of a series of errors. From establishing a situation in which medical transport was profit-motivated, to having a pilot accept – and subsequently fail to abort – a mission for which he and his aircraft were unsuitable, the Casco Bay crash represents the worst of helicopter EMS operations. The inevitable question for the current debate is: Could it happen again in Maine? Most pertinent to the issue of MMC landing versus Jetport landing, the question is "Could the helicopter crash near its landing site and place nearby individuals at risk?

Despite having been involved in HEMS since 1990, the consultant is unaware of any instances of bystander (*i.e.* not crew or ground personnel) fatality incurred from a helicopter crashing at or near a hospital-based helipad. However, in an effort to maximize the chances of identifying such an instance, the consultant contacted the single individual whose name is most identified with HEMS safety: Dr. Ira Blumen of Chicago, the author of a comprehensive 70-page report addressing HEMS safety.[34]

The question directed to Dr. Blumen was: How likely is it that the helicopter could crash at or near the hospital's helipad, injuring or killing neighbors? Of course, Blumen's response was that we are dealing with probabilities, not absolutes, but the good news is that the probabilities are – while nonzero – extraordinarily low. In fact, despite decades' experience in HEMS, including research for preparation of his safety report published in 2002,[34] Dr. Blumen did not recall *any* instance in which a person not involved with the helicopter transport was killed in a crash. In his reply to the consultant, he indicated[26]:

> "I know of only one accident that killed "someone on the ground." On 1/22/2001 (Air Evac, based out of Quincy, IL) a security guard who was supposed to be securing the helipad during take-off walked into the tail rotor and was killed. There have been numerous helipad accidents (rooftop and ground), but I do not know of any others that injured/killed non-crewmembers or the patient."

No one's memory is perfect, and there may indeed have been some instances that are not recalled by the consultant or safety experts. However, it is difficult to dispute the contention that a HEMS aircraft crash killing someone on the ground is an extremely rare event. Furthermore, it is obvious that such a crash could occur at any time during flight (not necessarily at or near the helipad), so the theoretical protection offered by vectoring the helicopter away from an on-site MMC landing pad is outweighed (by at least an order of magnitude) by the patient benefits expected to be accrued from use of an on-site pad. When considering the low, but nonzero, likelihood of a helipad-related crash, it may be worth considering another event, also of low but nonzero risk: a Portland citizen has a prolonged wait for an ambulance, due to delayed EMS response attributable to resource occupation on a Jetport-MMC ground transport.

In summary, the consultant has informed the City of Portland that his expertise lies outside the realm of safety. However, using the best available resources, the consultant has attempted to illuminate the understandably resonant safety issue and paint a rational picture of extremely low – even difficult to quantify – risk levels. One program, LFOM, will be the near-exclusive user of the pad; their pilots will be familiar with the helipad and will be available to train any other pilots as they assume positions rendering them likely to land at MMC. (This sort of cross-training occurs quite commonly in HEMS in general, and in New England in particular; the Boston hospitals' rooftop helipads are used by six HEMS services.) Furthermore, accident-related issues such as mechanical and fire hazards will apply minimally, since no HEMS maintenance or even refueling will occur on-site at MMC. In short, safety considerations do not appear to be a rational basis for avoiding construction of an on-site helipad. As the San Francisco Department of Public Health report on their own helipad issue concluded, "There is little evidence to support any danger to surrounding neighborhoods, even though some of these neighborhoods would be subject to helicopter overflight."[43]

Conclusion

The consultant entered this process with a goal of assessing what HEMS transports into MMC *currently* look like, in order to provide commentary on what the best model for the future may be. If the HEMS resource would have been found to provide "convenience" transports, or even transports for purely logistical reasons (*e.g.* off of a mountaintop), the consultant was more than prepared to identify the transports as being of noncritical nature. However, for reasons outlined elsewhere in this report, the current system of helicopter triage in the state of Maine is such that LFOM is used appropriately, and in fact the patient acuity for LFOM transports rivals that of any program with which the consultant is familiar – from rural or urban areas.

There are clearly described risks associated with adding extra time and patient transfers onto the out-of-hospital transport of either scene or interfacility runs. Equally clear are the benefits associated with expedited transport into tertiary care centers, for a wide variety of medical and surgical patients. Unfortunately, while in retrospect (and with limitations inherent to attempts to adjudicate clinical cause and effect) some patients "would have been fine" with the additional ground transport leg, the consultant believes the LFOM-MMC transport sample evidence supports a conclusion that any acuity or time-of-day based system of triage *away* from an on-site helipad, to the Jetport for bifurcated transport, is undesirable when viewed from the standpoint of the patient being transported, and indeed the EMS system as a whole.

Having an on-site MMC helipad is reasonably certain to translate into better-quality care, in terms of maximizing chances for benefit and minimizing chances of risk, to the people of Maine who undergo air medical transport. The current system of bifurcated transport has not been a disservice to the population served by MMC, but the available data very clearly support an upgrading of the hospital's capability to expedite transport into its critical care areas. In just about every clinical system, including the one by which LFOM and MMC operate to get patients into MMC, there is room for improvement. Construction and regular use of an on-site helipad at MMC appears to exemplify such an improvement for the hospital, for LFOM, and for the patients.

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<u>Appendix I: LFOM triage guidelines</u>

LIFEFLIGHT OF MAINE
GUIDELINES FOR HELICOPTER TRANSPORT

GENERAL GUIDELINES

Many patients who require transport to centers with specialized or tertiary level resources are appropriate for transport by ground ambulance. A select group of patients may benefit from the advantages that helicopter transport can offer. These advantages include:

Decreased response time and length of transport
Availability of highly trained medical crews and specialized equipment
Increased access to tertiary and definitive care facilities when the patient requires specific or timely treatment which is not available at the referring hospital or facility

Even though the guidelines below are useful, they are not necessarily all-inclusive and should not replace decisions about transport based on sound medical judgement. It is likely that patients appropriate for helicopter transport would have medical conditions that fulfill one or more of the general criteria listed below, and would as well include one or more of the specific criteria, which follow. Some general criteria include:

- The patient requires critical care life support (monitoring, personnel, medications, or specific equipment) during transport that is not available from the local ground ambulance service.
- The patient's clinical condition requires that the time spent out of the hospital environment (in transport mode) be as short as possible.
- The potential for delays which may be associated with ground transport is likely to worsen the patient's clinical status.
- The patient is located in an area which is inaccessible to regular ground traffic.
- The use of local ground transport team would leave the local area without adequate EMS coverage.

SPECIFIC GUIDELINES

<u>TRAUMA</u> – Patient at Scene: Maine EMS Prehospital Trauma Triage Protocol

<u>TRAUMA</u> – Patient at Hospital:

Central Nervous System

Spinal cord injury or major vertebral injury
Head injury with one or more of the following:
Lateralizing signs
Penetrating injury or open fracture (with or without CSF leak)
Depressed skull fracture
Glasgow Coma Scale < 12 or deterioration GCS
For Scene Responses

Chest

Major chest wall injury
Wide mediastinum or other signs suggesting great vessel injury

Cardiac injury
Patients who may require prolonged ventilation

Pelvis

Unstable pelvic ring disruption
Open pelvic fracture
Unstable pelvic fracture with shock or other evidence of continuing hemorrhage

Major extremity injuries

Fracture/dislocation with loss of distal pulses
Open long-bone fractures
Extremity ischemia

Multiple system injury

Head injury combined with face, chest, abdominal or pelvic injury
Burns
with associated injuries
greater than 20% total body surface area
involving the respiratory system
involving face, head, feet, hands, or genitalia
electrical burns
Multiple long-bone fractures
Injury to more than two body regions

Secondary deterioration (late sequelae of trauma)

Respiratory failure with mechanical ventilation required
Sepsis
Single or multiple organ system failure (deterioration in central nervous, cardiac, pulmonary, hepatic, renal, or coagulation systems)
Major tissue necrosis

Comorbid Factors

Age <5 or >55 years
Known cardiorespiratory or metabolic disease
Pregnancy
Immunosuppression

Evidence of high energy impact

Death of occupant in same car

ADULT MEDICAL SURGICAL

Cardiac

Patients with cardiogenic shock (or requiring IABP)
Patients with acute MI & contraindications to lytic therapy who are candidates for emergent PTCA
High risk patients with failed thrombolytic therapy (large AMI, previous MI, previous CABG, severe ongoing ischemia) who are candidates for rescue PTCA
Life threatening medically refractory arrhythmias
Patients with medically refractory, unstable or post-infarct angina
Patients with suspected acute ventricular septal defects
Patients with rapidly decompensating valvular heart disease
Selected patients with cardiac tamponade and hemodynamic compromise
Patients with symptoms or signs of aortic dissection
Patients with the following conditions: acute pulmonary edema, cardiomyopathy, infectious

endocarditis, severe pulonary hypertension, hypertensive crisis, congenital heart disease or need for specialized pacemaker therapy

Patients requiring acute intervention (i.e., IV nitroglycerin, antidysrhythmics, thrombolytics, anticoagulants, PTCA, emergent cardiac catheterization, CABG, emergency cardiac surgery, or pericardiocentesis) unavailable at referring institution.

Other Medical/Surgical or Critical Care

Status post cardiopulmonary arrest with need for definitive management capabilities

Patients requiring continuous intravenous vasoactive medications or mechanical ventricular assist to maintain a stable cardiac output

Patients who may require mechanical ventilator support or are at risk of having an unstable airway

Acute pulmonary failure requiring sophisticated pulmonary intensive care

Acute ischemic event (extremities, intestinal) which requires urgent diagnostic procedures/treatment not available at referring facility

Dissecting, leaking, or ruptured thoracic/abdominal aneurysm

Acute cerebrovascular accident in evolution requiring therapy or diagnostic procedures not available at the referring institution

Gastrointestinal hemorrhage leading to hypoperfusion or requiring blood transfusion, angiography or other procedures not available at the referring institution

Unstable patient with renal failure requiring acute hemodialysis unavailable at the referring institution

Severe poisonings or overdoses requiring intensive care

Severe hypothermia or hyperthermia requiring immediate active therapy

Uncontrollable seizure activity

Decompression illness or carbon monoxide poisoning requiring hyperbaric oxygen therapy

Significant acidosis not responsive to initial therapy

Patients requiring emergency cardiothoracic, vascular or neurosurgical diagnostic or operative procedures unavailable at the referring institution

Complications of cancer and chemotherapy; opportunistic infections with unstable vital signs

Patients who have met the criteria for brain death and whose families have consented for organ donation when urgent transport is required for organ salvage

Patients receiving organ transplantation, when time frame of donor organ viability is extremely limited (i.e., heart, lung)

Transfer of time-sensitive transplant organ from procurement hospital to site of transplant

HIGH RISK OBSTETRICS

The majority of obstetrical patients are appropriately transported by ground ambulance; there are some, however, in whom timeliness of transport is especially important. LifeFlight of Maine is dedicated to the rapid and safe transport of high risk obstetric patients. Before consideration of air transport, there should be a very high probability that delivery will not occur during transport. If delivery is imminent or likely to occur during transport, alternate care plans should be considered.

General complications

Medical care immediately available to the patient is not optimal for the patient's actual or predicted obstetrical, medical or surgical complications

There is reasonable expectation that the birth of one or more infants may require obstetric or neonatal intensive care beyond the capabilities of the referring institution

The patient's obstetrical, medical or surgical problems require continuous attendance by trained personnel not available at the referring institution

Obstetrical complications

Active premature labor with or without rupture of membranes at less than 34 weeks, or fetal weight is estimated at less than 2,000 grams
Severe pre-eclampsia or eclampsia
Abruptio placentae or placenta previa
Third trimester bleeding
Fetal hydrop

Medical Complications

Infections which may cause premature birth
Severe organic heart disease
Renal disease with deteriorating function or increasing hypertension
Drug overdose
Collagen vascular disease, metabolic disease (e.g. hyperthyroidism), or any disease considered to exceed the resources of the referring institution
Miscellaneous unusual or severe illnesses

Surgical complications

Trauma requiring intensive care or surgical correction beyond the capabilities of local institutions, or trauma requiring procedures that may cause premature labor
Acute abdominal emergencies at less than 34 weeks gestation or with a baby whose estimated weight is less than 2,000 grams
Thoracic emergencies requiring intensive care or surgical correction
Neurosurgical emergencies such as intracranial hemorrhage, expanding pituitary tumor, or brain tumor
In general the following patients who are in labor should **NOT** be considered for air transport

multiparous patients:

cervix dilated 3-4 cm or more with active labor and a substantially effaced cervix
contractions less than 5 minutes apart
history of rapidly progressing labor

primiparous patients:

cervix dilated 4-5 cm or more with active labor
contractions less than 5 minutes apart

PEDIATRICS

Patient experiencing or has a high risk of developing cardiac dysrhythmias or cardiac pump failure that requires interventions not available at the referring institution.
Patient experiencing or has a high risk of developing acute respiratory failure or respiratory arrest and is not responsive to initial therapy
Patient requires invasive airway procedures (including endotracheal or nasotracheal intubation, tracheotomy or cricothyroidotomy) and assisted ventilation.
Patient with any of the following vital signs:
respiratory rate <10 or >60 breaths per minute
systolic blood pressure <60mm Hg in a neonate
systolic blood pressure <65mm Hg in an infant <2 years of age
systolic blood pressure <70mm Hg in a child 2-5 years of age or systolic blood pressure <80mm Hg in a child 6-12 years of age
Patient with any of the following clinical conditions:
near-drowning with signs of hypoxia or altered mental status
status epilepticus
acute bacterial meningitis
acute renal failure

poisonings and overdoses with hemodynamic or neurologic instability
Reye's syndrome
Hypothermia
Multiple trauma
GCS <12 or deterioration
Intensive care to intensive care transfer when ground transport time is >30 minutes
Vasoactive drip required to maintain BP
Arterial pH <7.2
Patients within 48 hours of respiratory/cardiac arrest
Non-trauma patient requiring cardiothoracic, neuro or pediatric surgeon for emergent care unavailable at referring institution

NEONATAL

Infant requiring mechanical ventilation or CPAP
Premature infant with gestational age <30 weeks and complications
Body weight <1500 grams and complications
Supplemental oxygen >60%
Neonate with extra-pulmonary air leak, interstitial emphysema, or pneumothorax
Need for transfer to Neonatal unit when ground transport time is >30 minutes
Cardiac or respiratory arrest within 24 hours
Temperature instability
Neonate requiring vasopressor drip medications or repeated volume challenges to maintain BP
Neonates with seizure activity, congestive heart failure, or disseminated intravascular coagulation
Surgical emergencies including diaphragmatic hernias, necrotizing enterocolitis, abdominal wall defect, intussusception, suspected volvulus, congenital heart defects

GENERAL EXCLUSIONS TO HELICOPTER TRANSPORT

Terminally ill patients, unless they have an acute correctable problem of an emergent nature
Patients in full arrest at the referring institution who cannot be stabilized to a perfusing circulation
Incessant VF or VT with severe hemodynamic compromise
Advance directives precluding aggressive life prolonging measures
Anoxic encephalopathy/coma

Appendix II: National HEMS utilization guidelines

POSITION PAPER
NATIONAL ASSOCIATION OF EMS PHYSICIANS

GUIDELINES FOR AIR MEDICAL DISPATCH

David P. Thomson, MD, MS, Stephen H. Thomas, MD, MPH, for the 2002–2003 Air Medical Services Committee of the National Association of EMS Physicians

INTRODUCTION

Air medical transport has become a well-established part of the emergency medical services (EMS) system. Through the use of aircraft, patients are moved swiftly and safely throughout the world. However, for a number of reasons, the use of air medical transport remains somewhat controversial. One reason for this controversy is that debate continues to surround appropriate utilization of air medical transport. Since the topics of triage to air transport were last addressed by the National Association of EMS Physicians' (NAEMSP's) Air Medical Task Force (hereafter abbreviated as "the Task Force"), there has been significant evolution of thought concerning appropriateness of air medical dispatch. Therefore, the goal of this position paper is to outline current recommendations guiding utilization of air medical transport.

This position statement builds on earlier work by the Task Force and replaces two previous position statements.[1,2] The first NAEMSP position statement on the subject was published in *Prehospital and Disaster Medicine* in January-March 1992 as a contribution of the 1992 Task Force.[1] The 1994 Task Force published a follow-up paper addressing non-trauma and pediatric considerations.[2] The current Task Force members gratefully acknowledge the work of the previous documents' authors: Drs. Nicholas Benson, Catherine Carruba, Dan Hankins, Richard Hunt, and David Wilcox. The current authors have also drawn upon the work of other organizations, including the Association of Air Medical Services (AAMS)[3] and the American Academy of Pediatrics (AAP),[4] which have produced similar documents.

This position statement has also been endorsed by the Air Medical Physician Association (AMPA), by approval of its Board of Directors.

DISCUSSION

Air medical transport has grown to the point where we commonly speak of people being "life-flighted." As of this writing, the AAMS, which represents the vast majority of U.S. air medical providers, reports 271 air medical program members, 193 of which have a helicopter EMS component.[5] The growth of air medical transport is, at least in part, due to a perception that provision of such a service results in benefits to the patients and/or regions where air transport exists. In some cases, the benefit results from the increased level of care provided by the air medical crew; these individuals are generally trained to a higher level of care than available ground EMS providers. In other cases, the putative explanation for improved outcome is the increment in speed afforded by the air transport vehicle. However, there is continued debate surrounding use of air transport.

One source of debate is cost. Economic analyses have suggested that helicopters are cost-effective,[6] and that utilization of helicopters is no more expensive than deployment of similarly configured ground ambulances with comparable staffing levels and response times.[7] However, acceptance of these premises is far from universal, and acquisition and maintenance of aircraft undoubtedly represent a significant expense in an era of limited health care dollars. Within this economic envelope, payers for health care including commercial insurance, managed care organizations, and public payers, including Medicare and Medicaid in the United States and government sup-

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TABLE 1. Questions That Can Assist in Determining Appropriate Transport Mode

- Does the patient's clinical condition require minimization of time spent out of the hospital environment during the transport?
- Does the patient require specific or time-sensitive evaluation or treatment that is not available at the referring facility?
- Is the patient located in an area that is inaccessible to ground transport?
- What are the current and predicted weather situations along the transport route?
- Is the weight of the patient (plus the weight of required equipment and transport personnel) within allowable ranges for air transport?
- For interhospital transports, is there a helipad and/or airport near the referring hospital?
- Does the patient require critical care life support (e.g., monitoring personnel, specific medications, specific equipment) during transport, which is not available with ground transport options?
- Would use of local ground transport leave the local area without adequate emergency medical services coverage?
- If local ground transport is not an option, can the needs of the patient (and the system) be met by an available regional ground critical care transport service (i.e., specialized surface transport systems operated by hospitals and/or air medical programs)?

ported programs in the world, recognize the medical utility of air transport for selected patients.

Safety is also a consideration in the debate about utilization of air medical transport. Air ambulance crashes, although infrequent, are well publicized, and air transport programs must allocate both time and dollars in a continuing effort to maximize safety.

Another source of debate is the relatively limited literature directly addressing outcomes benefit associated with air transport. At the time the original NAEMSP and AAMS documents were produced, there was very little research available on which the committees could base their recommendations. Although this situation has improved somewhat during the last decade, research regarding the appropriate deployment of complex medical care systems remains in its infancy. This document represents what we believe to be the current state of the art, based upon a sometimes subjective interpretation of the best available evidence.

Some caveats must be considered prior to outlining the Task Force's guidelines. These caveats, at least as important as are the actual guidelines, address some limitations inherent to the process of creating this position statement.

First, and foremost, the specific criteria and diagnoses listed in the guidelines are *not* intended to be a comprehensive listing, but rather an indication of the types of entities for which air medical response may be appropriate. As a related note, the guidelines are intended to assist prehospital provider decision making, rather than override judgment of those at the patient's side. In fact, many EMS systems have their own criteria for air medical dispatch. Such criteria (e.g., specific mechanism-of-injury triage tools) inevitably differ between regions based on demographic, geographic, and health care resource considerations. Furthermore, air medical dispatch rules continue to evolve with increasing regionalization of nontrauma care (e.g., for patients with acute coronary or neurological syndromes). The growing number of specialized ground critical care vehicles has also impacted indications for air medical dispatch, as some patient populations traditionally transported by air are good candidates for high-level-of-care ground transport. It is also reasonable to assume that the nationwide issue of emergency eepartment ground ambulance "diversion" could affect helicopter utilization patterns. In short, no group of practitioners or researchers can foresee every circumstance; good medical care requires that scientific principles be individualized for each patient and situation. As an aid to guiding individual patient triage decision making, the questions as outlined in Table 1 may be helpful.

Just as appropriateness of air medical dispatch can be judged only in light of a given patient's situation, regional and logistic considerations are also necessary. For example, a patient with an amputation of a dominant thumb may require helicopter or fixed-wing evacuation from an offshore island or remote wilderness area; conversely, a patient with severe vehicular trauma occurring within or near city limits may be best served by ground transport.[6]

Due to the fact that most literature addresses helicopter (rotorwing) rather than airplane (fixed-wing) aircraft, this position statement concentrates on the former transport mode. However, general guidelines for fixed-wing transport are also provided. Additionally, as specialized (i.e., "critical care") ground transport continues to evolve, this modality will likely be used for some patients historically undergoing air transport.

It should be noted that, as applied to helicopter transport, these guidelines are for *response*, not necessarily *transport*. (In cases where fixed-wing transport is activated patients, will nearly always be transported unless there is a change in clinical status.) Even in the most conservative EMS system, there will be an occasional case where air transport is activated appropriately, but upon availability of further information it becomes clear that completion of the transport by air is not indicated. Examples of such cases include situations where patients at a trauma scene are re-evaluated and found to be either obviously uninjured or to have unsurvivable injuries (in these cases the air transport crew may best serve the patient by assisting ground EMS during surface transport to the nearest facility or by following local protocols for patient death).

Ground EMS services, air medical services, hospitals, and third-party payers should understand that in order to make the air transport resource available to those who need it, a certain level of overtriage is unavoidable. Also, decision making about patient transport should take into account the capabilities of local and regional EMS and hospitals. Given the inherent uncertainty surrounding prehospital diagnosis and triage, an EMS system with zero air transport overtriage is almost certainly underutilizing its helicopter resource. On the other hand, while this position statement is intended to address air medical dispatch (as considered prospectively), it must be emphasized that an ongoing process of utilization review is critical to optimizing utilization of the air transport resource. Such utilization review can be focused upon both triage characteristics (e.g., mechanism of injury) and retrospective review of patient course at the receiving hospital (e.g., early discharge without diagnostic or therapeutic intervention).

Just as it is important to appropriately incorporate air transport into the scene *and* interfacility transport needs of a region, utilization review should be aimed at both mission types. As for interfacility transports, the historical prerogative of referring hospital treating physicians to determine transport mode is subject to increasing scrutiny. Because of understandable concerns about Consolidated Omnibus Reconciliation Act/Emergency Medical Treatment and Labor Act (COBRA/EMTALA)-related liability for intratransport deterioration, referring physicians may occasionally overtriage patients to helicopter transport. It is hoped that these guidelines may help frame the transport decision-making process in such fashion as to optimize transport mode appropriateness, maximize resource utilization, and serve as a foundation to support case-by-case triage decisions made by referring physicians.

The increasing complexity of transport decision making has emphasized the importance of air transport services' medical directors being available for real-time consultation as to transport mode. Research has shown that regions may benefit from detailed assessment of their specific geographic/logistical situations, with generation of maps serving as guides to assist in air vs. ground triage.[8]

Prior to creating this position paper, the literature concerning the transport of trauma and nontrauma patients was reviewed and summarized by a subcommittee of the NAEMSP Air Medical Services Task Force. The reader is referred to these annotated bibliographies, published previously in *Prehospital Emergency Care*,[9,10] for an overview of studies addressing air transport and patient outcomes. The literature reviews are not comprehensive, and the literature has continued to grow even in the short interval between researching of the bibliographies and publication of the reviews. For example, recent studies have reinforced arguments in favor of helicopter transport of blunt trauma patients[11,12] and strongly suggested outcomes benefit for interfacility air transport for a subset of patients with acute myocardial infarction.[13] Additionally, the Task Force recognizes that air transport modalities should play a cooperative role in systemwide responses to disasters and mass casualty incidents; the potential contributions of air transport services in these situations are not discussed in this paper since they have been outlined in *Prehospital Emergency Care*.[14]

In summary, the guidelines that follow are offered as a noncomprehensive overview of clinical and logistical situations in which air medical dispatch may be appropriate. The Task Force offers these guidelines as an aid to EMS systems' operational planning, with the earlier mentioned caveats—most importantly, that no set of guidelines should be interpreted as dogma and that the judgment of those at the patient's side should always count foremost in decision making.

GUIDELINES

1. General
    a. Patients requiring critical interventions should be provided those interventions in the most expeditious manner possible.
    b. Patients who are stable should be transported in a manner that best addresses the needs of the patient and the system.
    c. Patients with critical injuries or illnesses resulting in unstable vital signs require transport by the fastest available modality, and with a transport team that has the appropriate level of care capabilities, to a center capable of providing definitive care.
    d. Patients with critical injuries or illnesses should be transported by a team that can provide intratransport critical care services.
    e. Patients who require high-level care during transport, but do not have time-critical illness or injury, may be candidates for ground critical care transport (i.e., by a specialized ground critical care transport vehicle with level of care exceeding that of local EMS) if such service is available and logistically feasible.

2. Comparative considerations for air transport modes
    a. Rotor-wing
        i. Advantages
            (a) In general, decreased response time to the patient (up to approximately 100 miles distance depending on logistics such as duration of ground transfer leg)
            (b) Decreased out-of-hospital transport time
            (c) Availability of highly trained medical crews and specialized equipment

- ii. Disadvantages
  - (a) Weather considerations (e.g., icing conditions, weather minimums)
  - (b) Limited availability as compared with ground EMS
- b. Fixed-wing
  - i. Advantages
    - (a) In comparison with rotor-wing, decreased response time to patients when transport distances exceed approximately 100 miles
    - (b) In comparison with ground transport, decreased out-of-hospital transport time
    - (c) Availability of highly trained medical crews and specialized equipment
    - (d) In comparison with rotor-wing, less susceptibility to weather constraints
  - ii. Disadvantages
    - (a) Requires landing at airport, with two extra transport legs between airports and the patient origin and destination
    - (b) In comparison with ground transport, more subject to weather-related unavailability (e.g., icing, snow)
    - (c) Overall, less desirable as a transport mode for severely ill or injured patients (though extenuating circumstances may modify this relative contraindication to fixed-wing use)

3. Logistical issues that may prompt the need for air medical transport
   - a. Access and time/distance factors
     - i. Patients who are in topographically hard-to-reach areas may be best served by air transport.
       - (a) In some cases patients may be in terrain (e.g., mountainside) not easily accessible to surface transport.
       - (b) Other cases may involve the need for transfer of patients from island environs, for whom surface water transport is not appropriate.
     - ii. Patients in some areas (e.g., in the western United States) may be accessible to ground vehicles, but transport distances are sufficiently long that air transport (by rotor-wing or fixed-wing) is preferable.
   - b. Systems considerations
     - i. In some EMS regions, the air medical crew is the only rapidly available asset that can bring a high level of training to critically ill/injured patients. In these systems, there may be a lower threshold for air medical dispatch.
     - ii. Systems in which there is widespread advanced life support (ALS) coverage, but such coverage is sparse, may see an area left "uncovered" for extended periods if its sole ALS unit is occupied providing an extended transport. Air medical dispatch may be the best means to provide patient care and simultaneously avoid deprivation of a geographic region of timely ALS emergency response.
     - iii. Disaster and mass casualty incidents offer important opportunities for air medical participation. These roles, too complex for detailed discussion here, are outlined elsewhere.[11]

4. Clinical situations for scene triage to air transport (also known as "primary" air transport) are outlined below. In some cases (e.g., flail chest), the diagnosis can be clearly established in the prehospital setting; in other cases (e.g., cardiac injury suggested by mechanism of injury and/or cardiac monitoring findings), prehospital care providers must use judgment and act on suspicion. Absent unusual logistical considerations as an overriding factor, scene air response involves rotor-wing vehicles rather than airplanes. As a general rule, air transport scene response should be considered more likely to be indicated when use of this modality, as compared with ground transport, results in more rapid arrival of the patient to an appropriate receiving center or when helicopter crews provide rapid access to advanced level of care (e.g., when a ground basic life support team encounters a multiple trauma patient requiring airway intervention).
   - a. **Trauma:** Scene response to injured patients probably represents the mode of helicopter utilization with the best supporting evidence.
     - i. General and mechanism considerations
       - (a) Trauma Score <12
       - (b) Unstable vital signs (e.g., hypotension or tachypnea)
       - (c) Significant trauma in patients <12 years old, >55 years old, or pregnant patients
       - (d) Multisystem injuries (e.g., long-bone fractures in different extremities; injury to more than two body regions)
       - (e) Ejection from vehicle
       - (f) Pedestrian or cyclist struck by motor vehicle
       - (g) Death in same passenger compartment as patient
       - (h) Ground provider perception of significant damage to patient's passenger compartment
       - (i) Penetrating trauma to the abdomen, pelvis, chest, neck, or head
       - (j) Crush injury to the abdomen, chest, or head
       - (k) Fall from significant height
     - ii. Neurologic considerations
       - (a) Glasgow Coma Scale score <10
       - (b) Deteriorating mental status
       - (c) Skull fracture
       - (d) Neurologic presentation suggestive of spinal cord injury
     - iii. Thoracic considerations
       - (a) Major chest wall injury (e.g., flail chest)
       - (b) Pneumothorax/hemothorax
       - (c) Suspected cardiac injury
     - iv. Abdominal/pelvic considerations
       - (a) Significant abdominal pain after blunt trauma
       - (b) Presence of a "seatbelt" sign or other abdominal wall contusion

      - (c) Obvious rib fracture below the nipple line
      - (d) Major pelvic fracture (e.g., unstable pelvic ring disruption, open pelvic fracture, or pelvic fracture with hypotension)
    - v. Orthopedic/extremity considerations
      - (a) Partial or total amputation of a limb (exclusive of digits)
      - (b) Finger/thumb amputation when emergent surgical evaluation (i.e., for replantation consideration) is indicated and rapid surface transport is not available
      - (c) Fracture or dislocation with vascular compromise
      - (d) Extremity ischemia
      - (e) Open long-bone fractures
      - (f) Two or more long-bone fractures
    - vi. Major burns
      - (a) >20% body surface area
      - (b) Involvement of face, head, hands, feet, or genitalia
      - (c) Inhalational injury
      - (d) Electrical or chemical burns
      - (e) Burns with associated injuries
    - vii. Patients with near drowning injuries
  - b. **Nontrauma**: At this time the literature support for primary air transport of noninjured patients is limited to logistical considerations. It is conceivable that clinical indications for scene air response may be identified in the future. However, at this time prehospital providers should incorporate logistical considerations, clinical judgment, and medical oversight in determining whether primary air transport is appropriate for patients with nontrauma diagnoses.

5. Clinical situations for air transport in **interfacility** transfers are best summarized as being present when: 1) patients have diagnostic and/or therapeutic needs which cannot be met at the referring hospital, and 2) factors such as time, distance, and/or intratransport level of care requirements render ground transport nonfeasible.
  - a. **Trauma**: Injured patients constitute the diagnostic group for which there is best evidence to support outcome improvements from air transport.
    - i. Depending on local hospital capabilities and regional practices, any diagnostic consideration (suspected, or confirmed as with referring hospital radiography) listed above under "scene" guidelines may be sufficient indication for air transport from a community hospital to a regional trauma center.
    - ii. Additionally, air transport (short- or long-distance) may be appropriate when initial evaluation at the community hospital reveals injuries (e.g., intra-abdominal hemorrhage on abdominal computed tomography) or potential injuries (e.g., aortic trauma suggested by widened mediastinum on chest x-ray; spinal column injury with potential for spinal cord involvement) requiring further evaluation and management beyond the capabilities of the referring hospital.
  - b. **Cardiac**: Due to regionalization of cardiac care and the time-criticality of the disease process, patients with cardiac diagnoses often undergo interfacility air transport. Patients with the following cardiac conditions may be candidates for air transport:
    - i. Acute coronary syndromes with time-critical need for urgent interventional therapy (e.g., cardiac catheterization, intra-aortic balloon pump placement, emergent cardiac surgery) unavailable at the referring center
    - ii. Cardiogenic shock (especially in presence of, or need for, ventricular assist devices or intra-aortic balloon pumps)
    - iii. Cardiac tamponade with impending hemodynamic compromise
    - iv. Mechanical cardiac disease (e.g., acute cardiac rupture, decompensating valvular heart disease)
  - c. **Critically ill medical or surgical patients**: These patients generally require a high level of care during transport, may benefit from minimization of out-of-hospital transport time, and may also have time-critical need for diagnostic or therapeutic intervention at the receiving facility. Ground critical care transport is frequently a viable transfer option for these patients, but air transport may be considered in circumstances such as the following examples:
    - i. Pretransport cardiac/respiratory arrest
    - ii. Requirement for continuous intravenous vasoactive medications or mechanical ventricular assist to maintain stable cardiac output
    - iii. Risk for airway deterioration (e.g., angioedema, epiglottitis)
    - iv. Acute pulmonary failure and/or requirement for sophisticated pulmonary intensive care (e.g., inverse-ratio ventilation) during transport
    - v. Severe poisoning or overdose requiring specialized toxicology services
    - vi. Urgent need for hyperbaric oxygen therapy (e.g., vascular gas embolism, necrotizing infectious process, carbon monoxide toxicity)
    - vii. Requirement for emergent dialysis
    - viii. Gastrointestinal hemorrhages with hemodynamic compromise
    - ix. Surgical emergencies such as fasciitis, aortic dissection or aneurysm, or extremity ischemia
    - x. Pediatric patients for whom referring facilities cannot provide required evaluation and/or therapy
  - d. **Obstetric**: In gravid patients, air transport's advantage of minimized out-of-hospital time must be balanced against the risks inherent to intratransport delivery. If transport is necessary in a patient in whom delivery is thought to be imminent, then a ground vehicle is usually appropriate, although in some cases

Appendix III: Normal chain of events during various transport situations

One of the jobs assigned to the consultant was to prepare descriptions reflecting the logistics of "typical" transports. Indeed, an overview of the transport continuum, starting with the onset of illness or injury and carrying through to MMC arrival, may be useful. Other sections of the consultant's report deal in detail with the occurrences after LFOM is called; this Appendix is intended to give information relevant to the "pre-LFOM" course and chain of events.

Transports are categorized as either primary ("scene runs," usually for trauma but sometimes for other conditions) or secondary ("interfacility runs" – from referring hospital to receiving center). This section will outline a typical chain of events occurring for each transport type. Additionally, example cases from the LFOM-MMC review cohort will be used to give an idea of the timing and other parameters associated with some illustrative situations.

Overview of transport logistics for scene runs

A scene run entails helicopter response directly to the patient. In Maine, the aircraft is called, by any of a variety of personnel including, but not limited to: police, emergency medical technicians, fire/rescue workers, or in some cases others (*e.g.* forestry personnel) who are physically present at the accident or illness scene and who are enabled to make a determination of necessity for HEMS use. This determination is made based upon the triage criteria of the Maine EMS system. The Maine EMS protocols are in line with those used in other regions of the country.

For scene runs, until helicopter arrival the patient is provided whatever aid is available (for instance, basic life support from a fire/rescue service, or advanced life support from a paramedic). Depending on the scene's layout and topography, the helicopter may either land in close proximity to the patient, or – as a less desirable but safety-compelled option – at a more distant site necessitating ground ambulance transport to get the crew to the patient.

Upon arriving at the patient, HEMS crews on a scene run usually assume responsibility for the medical decision-making. Patients are stabilized for HEMS transport, and are then transferred to the helicopter. If not done previously, radio contact is established with the receiving hospital to make them aware of the impending arrival of the scene patient, to enable execution of appropriate preparations (*e.g.* assembly of a trauma team). Upon landing at the Jetport, the helicopter crew offloads the patient for a ground transport to MMC. From the Jetport, patient transfer logistics to MMC are as outlined elsewhere in this report.

Overview of transport logistics for interfacility runs

An interfacility transport occurs after a physician caring for the patient at a referring hospital makes a determination that the patient's clinical needs (for either diagnosis or therapy) outstrip those available at the local facility. Additionally, for HEMS transport the referring physician makes a determination that the air, as opposed to ground, transport mode is most fitting in the given situation (*e.g.* for acuity and time-criticality reasons). Just as is the case for scene transports, there are guidelines to assist the attending physician in making the determination as to optimal transport mode.

Concurrent to the request for HEMS, the referring physician discusses the case with receiving physicians at the tertiary center. The helicopter lands at the referring hospital's helipad – given the small size of most referring hospitals, only in uncommon cases is there bifurcated transport of any significant distance – and the crew enters the referring hospital to begin the transport process.

Unlike the case as occurs with scene response, the HEMS crew arriving at the patient for interfacility transport doesn't usually assume primary responsibility for medical decision-making; a physician is usually present and the HEMS crew discusses the patient's case with the referring medical staff.

Subsequent to an appropriate exchange of clinical information, the patient is loaded onto the aircraft – in some cases after a ground vehicle ride of a minute or two – and transported to the receiving center. As was noted for scene runs, radio report is given to the receiving facility while the aircraft is *en route*, and the final ground transport leg from the Jetport to MMC occurs as outlined elsewhere in this report.

Review of cases illustrating "pre-LFOM" scene & interfacility logistics

Recounting of some actual patients in the set of 100 LFOM-MMC transports can help illustrate the events and times associated with HEMS mission types. Applicable times for the onset of illness or injury, or time parameters for the "pre-LFOM" course, were often unavailable, but some representative cases serve to paint a picture of logistics in scene and interfacility transports of varying nature.

A sample case of a fairly "standard" scene run is given by the following vignette. A child was involved in vehicular trauma, and is seen by prehospital providers who called for HEMS at 0947. LFOM was dispatched at 0948, lifted off at 0957 (a longer delay than usual), and arrived at the patient's side at 1014. A few minutes were required to stabilize the patient, and LFOM departed the scene at 1020, with a Jetport arrival time of 1030.

Sometimes LFOM is called and requested to be on "standby" in cases where those at the scene suspect, but are not certain, that HEMS will be necessary. This occurred in the instance of a patient with penetrating trauma. The patient was initially evaluated by local ground EMS at 1315; those calling the ground ambulance had also notified LFOM to be on "standby" in a 1301 contact. Upon arriving at the patient, ground EMS requested LFOM dispatch and the helicopter arrived at the patient at 1339. After an expedited patient evaluation the patient was taken to Portland, with a 1416 landing at the Jetport.

Occasionally, LFOM is called initially for scene response, with subsequent change to request for an interfacility mission. In the instance of one trauma patient, LFOM was called at 1243. Before LFOM arrived at the scene (and presumably due to high patient acuity), it was decided by ground EMS to take the patient to the local hospital. At 1258, LFOM was asked to re-task the transport as an interfacility mission. The helicopter arrived at the referring hospital at 1327, and the crew was at the patient's bedside at 1334. The aircraft left the referring hospital at 1407, landing at the Jetport at 1438. After a 5-minute transfer into the ground ambulance for the Jetport-to-MMC leg, the patient arrived at the MMC intensive care unit at 1450.

Following is a typical example of an interfacility LFOM transport of an injured patient for whom pre-hospital times are documented. A trauma patient was at the scene, to which location a local advanced life support ground unit was dispatched at 1548. The responding ground EMS unit arrived at the patient at 1600, and spent 7 minutes stabilizing him for transport, leaving the trauma scene for the local hospital at 1607. The patient arrived at the local hospital at 1618, and LFOM was called at 1709. The helicopter landed at the local hospital at 1735, with the crew arriving at the patient's bedside ten minutes later (1745). Stabilization of the patient for transport, and transfer to the helicopter, required a half-hour; LFOM left the referring hospital at 1815 and landed at the Portland Jetport at 1831.

Following is an example of time course in an interfacility cardiac transport. This patient had chest pain upon awakening at home at 0530. An ambulance was called, and arrived at the patient's home at 0540. The patient was in the local hospital at 0558; his initial physician evaluation there was timed 0605. In this case, the patient's cardiac syndrome proved refractory to standard therapy, and LFOM was called (and the crew was dispatched) at 0640. The helicopter landed at the referring facility at 0733, and the crew was at the patient at 0738. After patient stabilization for transport, LFOM departed the local hospital at 0806. The aircraft landed at the Jetport at 0832, and the patient underwent ground transport to the MMC. He arrived at MMC at 0843 and was taken directly to the cardiac cath lab.

A final example illustrates what happens when a patient presents to a hospital at which HEMS is based. This case, of an interfacility transport of a patient who presented by private vehicle, involved a patient with breathing problems. After transport by private vehicle to an outlying ED, to which facility the patient arrived at 0547, LFOM was called at 0659. The LFOM crew was dispatched ("paged out") at 0700 and arrived at the patient at 0716. Stabilization for transport occupied the time span to 0752, at which time the patient left the referring facility, arriving at Portland's Jetport at 0804.

It is hoped that this appendix illustrates some of logistics and times associated with the "pre-LFOM" time frame. The vignettes demonstrate that different types of patients can have markedly different logistics needs, and that there are many steps in the time course from onset of illness (or injury) through arrival at MMC.

Tab 5

Fly Neighborly Guide

Produced by the Fly Neighborly Committee

Helicopter
Association
International

I Fly Neighborly

Revised February 1993

Fly Neighborly Guide

prepared by the
Helicopter Association International
Fly Neighborly Committee

Revised February 1993

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Foreword

The Fly Neighborly program is a voluntary noise reduction program designed to be implemented worldwide by local helicopter operators, large and small. This program includes all types of civil, military and governmental helicopter operations.

In the fall of 1981, the U. S. Federal Aviation Administration (FAA) agreed to withdraw its Notice of Proposed Rulemaking (NPRM) on helicopter noise while technical data were acquired, with the understanding that the helicopter industry would implement a voluntary noise reduction program. We should not, however, consider the Fly Neighborly program as merely a stop-gap measure, cobbled up to preclude federal regulation. After all, the public commonly asks:

- How is technology advancing to make helicopters quieter?
- When will this technology be in daily use?

Clearly, new technology is creating quieter, more advanced equipment every day, and this equipment will eventually be commercially available. Until then, the Fly Neighborly program offers the technical information necessary for helicopter operators to use current equipment as quietly as practical, and to communicate to the public their efforts to make helicopter operations compatible with nearly all land uses.

The Helicopter Association International (HAI) Heliports and Airways Committee (HAC) originally organized this program through the HAC's Fly Neighborly Steering Committee. This committee is composed of members of HAI and governmental representatives, including the FAA, the military, and other associations. Officially launched in February 1982, the program has gained international acceptance. In the U. S. the program has gained the full support of helicopter operators, regional associations, manufacturer, pilots and communities throughout the country. Federal, state and local government agencies have embraced the program and taken an active part in sponsoring Fly Neighborly presentations in conjunction with safety seminars and other activities. Worldwide, the helicopter industry and its related communities are being informed about the Fly Neighborly Program.

Objectives

The Fly Neighborly program addresses noise abatement and public acceptance objectives with programs in the following areas:

- pilot and operator awareness,
- pilot training and indoctrination,
- flight operations planning,

- public acceptance and safety, and
- sensitivity to the concerns of the community.

About This Guide

The *Fly Neighborly Guide* is published under the auspices of the Helicopter Association International to promote helicopter noise abatement procedures. It is intended to serve as a guide only, and is by no means comprehensive.

Purpose

These guidelines are intended to assist pilots, operators, managers and designated Fly Neighborly officers to establish an effective, self-sustained Fly Neighborly program. The flight procedures and concepts outlined herein must be further tailored to suit local needs, and to ensure that local or regional organizations cooperate to develop a strong, well-organized and disciplined approach to achieving Fly Neighborly objectives.

Organization

This guide is divided into seven sections.The first section deals with pilot training and related noise abatement procedures. The second section describes what operators can do to promote noise abatement operations. The third section is designed to deal with community concerns and issues of public acceptance. An appendix explains the causes of helicopter noise. A glossary defines the acronyms used in this book, and the last two sections provide names, addresses, and phone numbers of helicopter manufacturers and regional affiliate members of HAI.

Administration

The HAI solicits new ideas, comments, and recommendations to improve the program. HAI's Fly Neighborly Committee, Public Relations Advisory Committee (PRAC), Safety Committee, and Heliports Committees are focal points for the development of new technical material in their respective areas. Additional guides and camera-ready copy for Fly Neighborly logos may be obtained from HAI.

The Fly Neighborly committee monitors the Fly Neighborly program, and distributes new information to participants. The committee also maintains a listing of participants and Fly Neighborly support materials.

Individuals, operators, or agencies desiring additional information should contact the Fly Neighborly staff liaison at:

Helicopter Association International
1619 Duke Street
Alexandria, VA 22314 U. S. A.
(703) 683-4646 Fax: (703) 683-4745 Telex: 89-615 HAI

Pilot Training

Scope

The scope of the pilot training program includes:

- initial and recurrent flight training for pilots,
- the incorporation of noise data into flight manuals,
- preparing and distributing specific helicopter noise data,
- preparing and distributing recommended noise abatement procedures,
- organizing and holding operator and manufacturer seminars, and
- providing environmental and supervisory personnel training courses.

Basic Guidelines for Pilot Training

Public acceptance for our helicopter operations can be obtained in several ways. One is noise abatement. Crew training in noise abatement procedures is therefore vital. The following guidelines for noise abatement training are suggested:

- Select training teams for ground and flight training, usually two or three people who have extensive metropolitan operations experience.
- Standardize presentations.
- Maintain complete files of all persons trained.
- Circulate critique or comment sheets at all meetings or training sessions, and stress that all suggestions, ideas and comments will be considered.
- Make the necessary changes in training and publications that result from the feedback.
- Maintain an open-door policy to all participants, flight crews and the public.
- Determine the effect of this training on the public. Has it been positive or negative?
- Record all complaints and include all relevant details, such as the time, date, location, altitude, or weather.
- Follow up with proficiency training every six months. Emphasize the importance of public contacts, and the necessity of good community relations.
- Expand these guidelines to cover local needs.

Basic Guidelines for Noise Abatement

Although this section offers a number of noise abatement techniques, here are a few simple guidelines to remember:

- Avoid noise-sensitive areas altogether when possible. Instead, follow:
  - — high ambient noise routes such as highways, or
  - — unpopulated routes such as waterways.

If you must fly near noise-sensitive areas:

- maintain an altitude of at least 1000 feet where possible,
- reduce your speed if you are flying above normal cruising speed,
- observe low-noise speed and descent settings,
- avoid sharp maneuvers,
- use high takeoff and descent profiles, and
- vary your route—repetition is annoying.

It has also been reported that flights conducted down arterials in noise-sensitive areas are less likely to generate complaints than routes that visually intrude on people's privacy, such as those that cross residential backyards.

Recommended Noise Abatement Procedures

Advisory Circular AC91.36C
Department of Transportation
Federal Aviation Administration
Washington, D.C.

March 19, 1982

Subject: VFR Flight Near Noise-Sensitive Areas

1. PURPOSE. This advisory circular encourages pilots making VFR flights near noise-sensitive areas to fly at altitudes higher than the minimum permitted by regulation and on flight paths which will reduce aircraft noise in such areas.

2. CANCELLATION. Advisory Circular 91.36A, VFR Flight Near Noise-Sensitive Areas, dated July 19, 1974, is cancelled.

3. BACKGROUND.

a. The Federal Aviation Administration continually receives complaints concerning low-flying aircraft over noise-sensitive areas. These complaints have prompted requests for regulatory action prohibiting low-altitude flight over identified noise-sensitive locations. We believe that a satisfactory solution can be realized by means of a pilot/industry cooperative endeavor rather than through the regulatory process.

b. Increased emphasis on improving the quality of the environment requires continued effort to provide relief and protection from aircraft noise.

c. Excessive aircraft noise can result in discomfort, inconvenience, or interference with the use and enjoyment of property, and can adversely affect wildlife. It is particularly undesirable near outdoor assemblies of persons, churches, hospitals, schools, nursing homes, noise-sensitive residential areas, and National Park Areas which should be preserved as important historic, cultural, and natural aspects of our national heritage.

d. Adherence to the practices described below would be a practical indication of pilot concern for environmental improvement, would build support for aviation, and forestall possible regulatory action.

4. VOLUNTARY PRACTICES.

a. Avoidance of noise-sensitive areas, if practical, is preferable to overflight at relatively low altitudes.

b. Pilots operating fixed- and rotary-wing aircraft under VFR over noise-sensitive areas should make every effort to fly not less than 2,000 feet above the surface, weather permitting, even though flight at a lower level may be consistent with the provisions of FAR 91.79, Minimum Safe Altitudes.

Typical of noise-sensitive areas are: outdoor assemblies of persons, churches, hospitals, schools, nursing homes, residential areas designated as noise-sensitive by airports or by an airport noise compatibility plan or program, and National Park Areas (including Parks, Forest, Primitive Areas, Wilderness Areas, Recreation Areas, National Seashores, National Monuments, National Lakeshores, and National Wildlife Refuge and Range Areas).

c. During departure or arrival from/to an airport, climb after takeoff and descent for landing should be made so as to avoid prolonged flight at low altitudes near noise-sensitive areas.

d. This procedure does not apply where it would conflict with ATC clearances or instructions or where an altitude of less than 2,000 feet is considered necessary by a pilot in order to adequately exercise his or her primary responsibility for safe flight.

5. COOPERATIVE ACTIONS. Aircraft operators, aviation associations, airport managers, and others are asked to assist in implementing the procedures contained herein by publicizing them and distributing information regarding known noise-sensitive areas.

R. J. Van Vuren
Director, Air Traffic Service

How to Operate Helicopters More Quietly

The following sections were also written by Charles Cox, a research project engineer with Bell Helicopter. In these sections, Mr. Cox explains how light and medium-weight helicopters can be flown as quietly as possible. Although the information offered by Mr. Cox may be somewhat specific to Bell helicopters, the general information he offers applies to the operation of all helicopters.

Noise Abatement Flight Procedures for Light Helicopters

In general, you can eliminate the most offensive sounds of the 206A helicopter by keeping it out of the slap region shown in Figure 7 (see Appendix A). This is not always possible, of course, and when the slap regions cannot be avoided, fly through them as quickly as possible. There are also other methods of reducing helicopter noise, and you should use them when you can, whether you are flying within the slap boundary or not.

Routes and Airspeeds

- Fly at the highest practical altitude when approaching metropolitan areas.
- Select a route into the terminal over the least populated area.
- Follow major thoroughfares or railway roadbeds.
- Avoid flying low over residential and other densely populated areas.
- If you must fly over such areas, maintain a cruise speed of approximately 95 knots.
- Select the final approach route with due regard to the type of neighborhood surrounding the terminal, and the neighborhood's sensitivity to noise. Assess this sensitivity beforehand for each terminal. Some guidelines are:
    - Keep the terminal between the helicopter and the most noise-sensitive building or area on approach.
    - If the terminal is surrounded by noise-sensitive areas, approach at the steepest practical glide slope.
    - Avoid flying directly over hospitals, nursing homes, schools, and other highly noise-sensitive facilities.
    - If the terminal is in or near a noise-sensitive area, use the noise-abatement approach and landing technique described below and illustrated in Figure 1.

Approach and Landing

1. When commencing approach, follow one of these two procedures:
    a. First establish a rate of descent of at least 500 fpm.
    b. Then reduce airspeed while increasing the rate of descent to at least 800 fpm.

    or:

    a. Hold the rate of descent to less than 200 fpm while reducing airspeed to about 57 knots.
    b. Then increase the rate of descent to at least 800 fpm.

2. At a convenient airspeed between 50 and 80 knots, set up an approach glide slope while maintaining the 800 fpm or greater rate of descent.
3. Increase the rate of descent if the main rotor tends to slap, or if you want a steeper glide slope.
4. As you approach the flare, reduce the airspeed to below 60 knots before decreasing the rate of descent.
5. Execute a normal flare and landing, decreasing the rate of descent and airspeed appropriately.

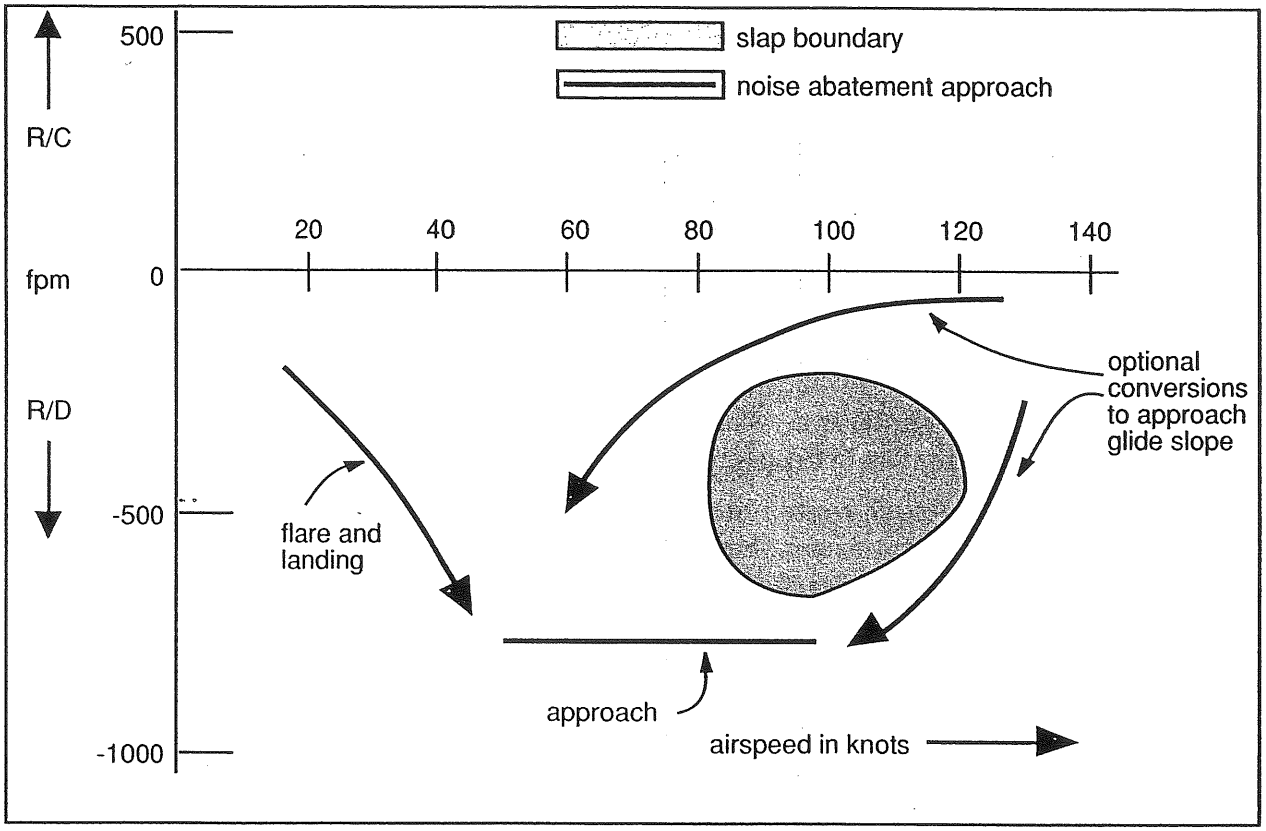

Figure 1. *Noise Abatement Flight Technique for Light Helicopters*

The basic difference between this approach technique and a normal one is that this one avoids blade slap. Both procedures give approximately the same airspeed during the approach, but the quieter technique uses a glide slope that is a few degrees steeper. Once you have made the transition from cruise to the approach glide slope, you can tailor your airspeed and rate of descent to fit local conditions, avoid unsafe regimes, and still guarantee minimum noise.

Departure

Takeoffs are reasonably quiet operations, but you can limit the total ground area exposed to helicopter sound by using a high rate of climb and making a smooth transition to forward flight. Your departure route should take you over areas which are the least sensitive to noise.

Maneuvers

Avoid rapid, high *g* turns, as a general rule. When the flight operation requires turns, perform them smoothly. Be smooth in all other maneuvers also.

Noise Abatement Flight Procedures for Medium Helicopters

In general, you can eliminate the most offensive noise of the 204B, 205A, 212, and other medium helicopters by keeping them out of the slap regions shown in Figures 8 and 9 (see Appendix A). This is not always possible, of course, and when the slap regions cannot be avoided, fly through them as quickly as possible. There are also other methods of reducing helicopter noise, and you should use them when you can, whether you are flying within the slap boundary or not.

Routes and Airspeeds

- Fly at the highest practical altitude when approaching metropolitan areas.
- Select a route into the terminal over the least populated area.
- Follow major thoroughfares or railway roadbeds.
- Do not exceed 110 knots when within five miles of suburban areas.
- Within three miles of densely populated areas, maintain a cruise speed of approximately 100 knots, and reduce rpm to the minimum allowed by the flight manual of the particular helicopter.
- Select the final approach route with due regard to the type of neighborhood surrounding the terminal, and the neighborhood's sensitivity to noise. Assess this sensitivity beforehand for each terminal. Some guidelines are:
  - — Keep the terminal between the helicopter and the most noise-sensitive building or area on approach.
  - — If the terminal is surrounded by noise-sensitive areas, approach at the steepest practical glide slope.
  - — Avoid flying directly over hospitals, nursing homes, schools, and other highly noise-sensitive facilities.
  - — If the terminal is in or near a noise-sensitive area, use the noise-abatement approach and landing technique described below and illustrated in Figure 2.

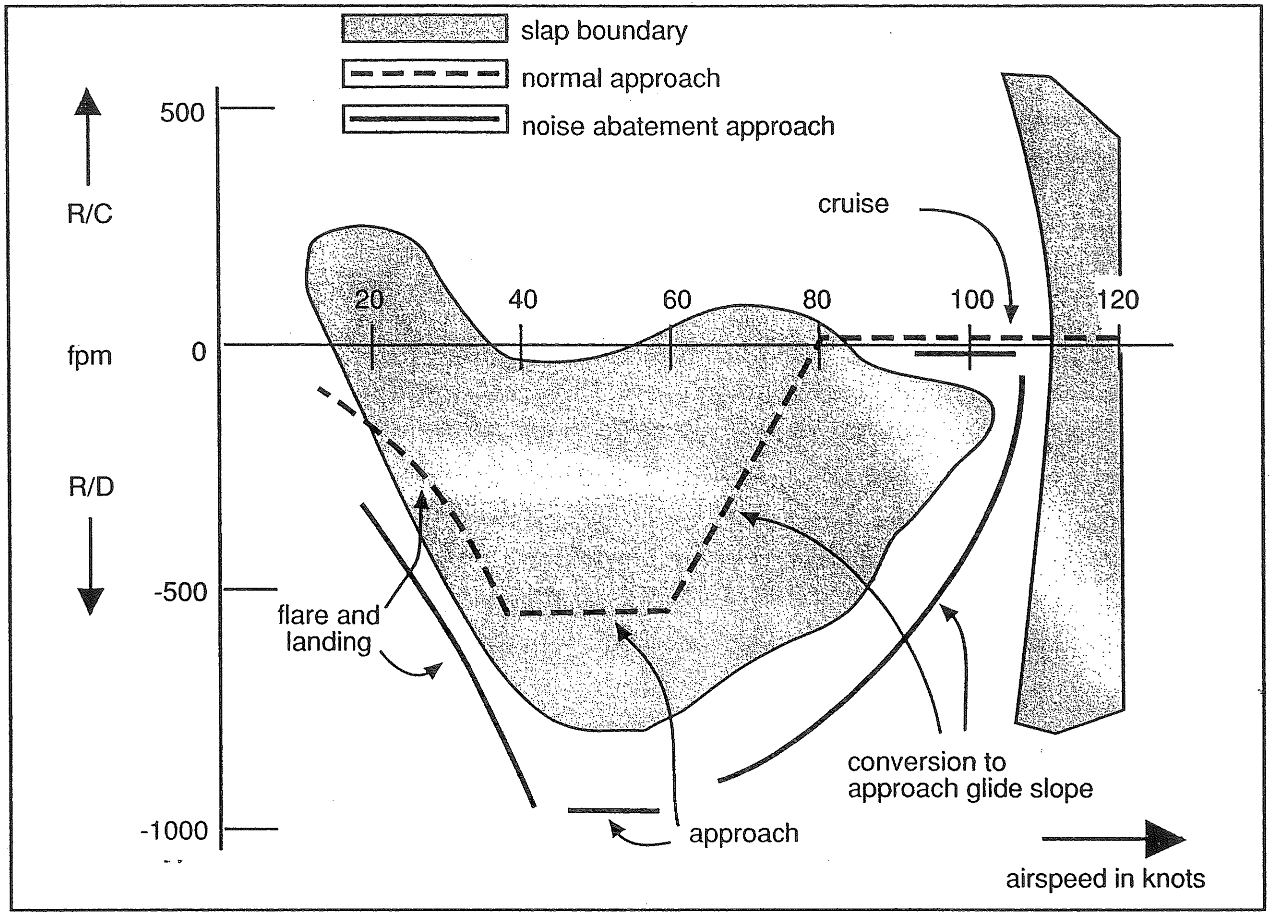

Figure 2. *Noise Abatement Flight Technique for Medium Helicopters*

Approach and Landing

1. When commencing approach, begin descent at a rate of at least 200 fpm before reducing airspeed.
2. Then reduce airspeed while increasing the rate of descent to about 800 fpm.
3. At a convenient airspeed between 50 and 80 knots, set up an approach glide slope while maintaining the 800 fpm rate of descent.
4. Increase the rate of descent if the main rotor tends to slap, or if you want a steeper glide slope.
5. As you approach the flare, reduce the airspeed to below 50 knots before decreasing the rate of descent.
6. Execute a normal flare and landing, decreasing the rate of descent and airspeed appropriately.

The basic difference between this quieter approach technique and a normal one is that you begin your descent before reducing your airspeed. Both procedures give approximately the same airspeed during the approach, but the quieter technique uses a glide slope that is a few degrees steeper. Once you have made the transition from a cruise to the approach glide slope, you can tailor your airspeed and rate of descent to fit local conditions, avoid unsafe regimes, and still guarantee minimum noise.

This noise-abatement flight technique reduces the ground area exposed to a given noise level by as much as 80 percent. Figure 3 shows this for a conventional straight-in approach.

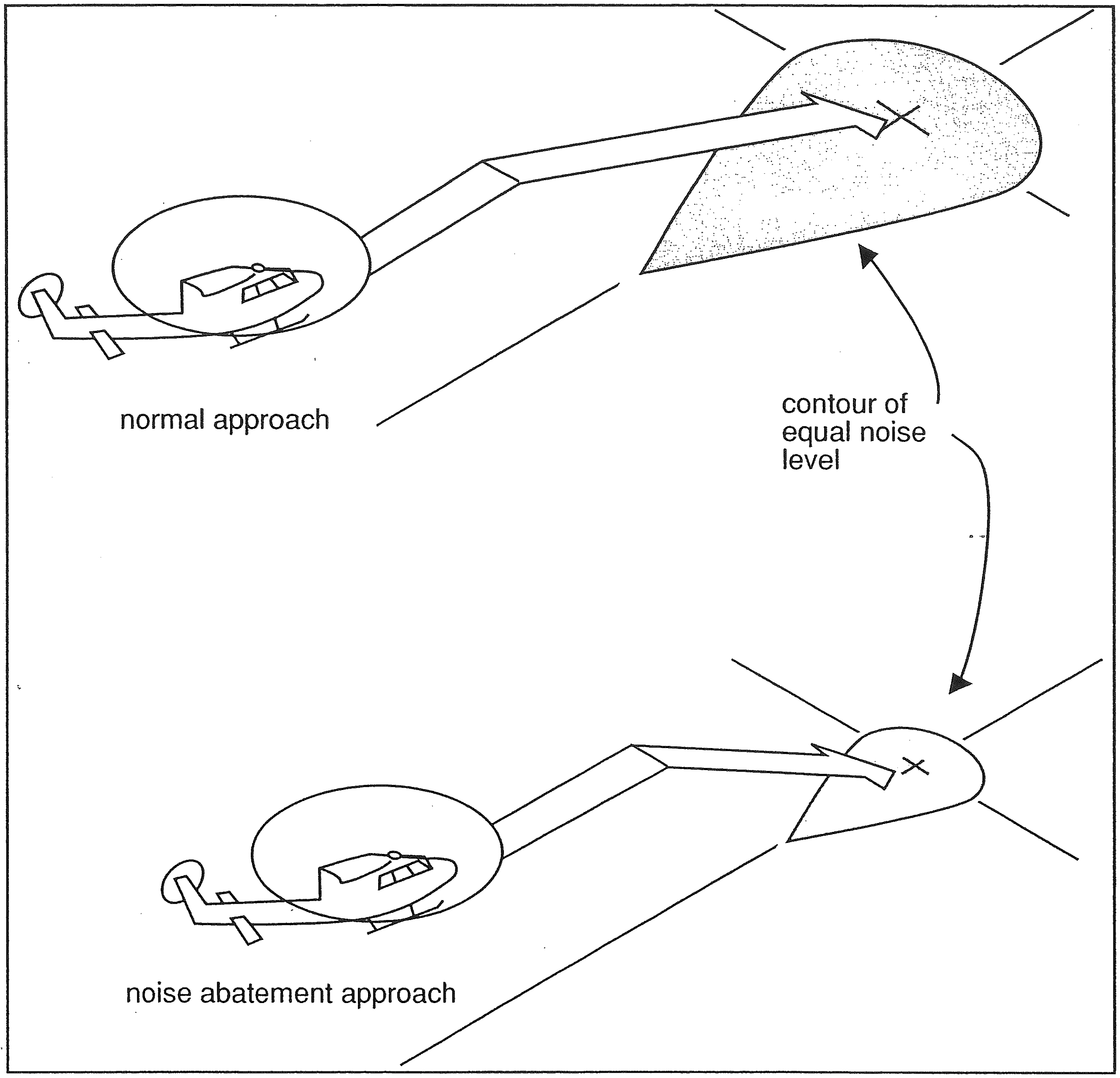

Figure 3. *Ground Noise Exposure Footprint*

Departure

Takeoffs are reasonably quiet operations, but you can limit the total ground area exposed to helicopter sound by using a high rate of climb and making a smooth transition to forward flight. Your departure route should take you over areas which are least sensitive to noise.

Maneuvers

Avoid rapid, high *g* turns, as a general rule. When the flight operation requires turns, perform them smoothly. Be smooth in all other maneuvers, also.

Manufacturers' Noise Abatement Procedures

The Fly Neighborly program requires the cooperation and support of helicopter manufacturers as well. While pilots and operators have the greatest influence in the short-term, manufacturers can also have an impact by disseminating information and engaging in longer-term research efforts.

HAI requests that manufacturers promote noise abatement in helicopter flight by investigating and publishing piloting techniques to reduce sound footprints and mitigate objectionable sound levels for each model of helicopter.

HAI further requests that manufacturers integrate these techniques into pilot training, and publish the resulting information. Specifically, HAI requests that manufacturers:

- publish general piloting techniques in industry publications and training manuals,
- publish piloting techniques for each model of aircraft in the unapproved or supplemental section of their aircraft flight manuals, and
- supply appropriate manuals, charts, or pamphlets for use in public hearings or presentations.

The following section presents noise abatement procedures for specific models of aircraft. This information represents all of the data currently available from these manufacturers. As new data becomes available, it will be distributed for inclusion in this document.

The back of this handbook lists contact names, addresses, and phone numbers for various helicopter manufacturers. If noise abatement procedures for the helicopter you fly are not included below, you may wish to contact the manufacturer directly.

NOTE The procedures specified on the following pages are manufacturers' recommendations for flying in the quietest manner possible. They are to be construed as advisory guidelines only. If differences arise between these noise abatement procedures and standard operating procedures, fly according to standard operating procedures.

Above all, if flying according to these noise abatement procedures conflicts with operating the aircraft in a safe manner, then all safety-related procedures take precedence.

Aerospatiale AS350, AS355, AS365, and AS332

General

Maximum distance and altitude separation from noise-sensitive areas is the most effective means of noise abatement.

Control movement should be gradual and smooth.

Noise exposure is lower in front of than behind the helicopters.

Takeoff and Climb

Climb at the best rate of climb in order to reach altitude as soon as possible.

Enroute and Cruise

Where possible, maintain a minimum altitude of 500 feet above ground level.

Approach and Landing

Approach and descend as steeply as possible.

Aerospatiale SA 365N

General

Maximum distance and altitude separation from noise-sensitive areas is the most effective means of noise abatement.

Control movement should be gradual and smooth.

Noise exposure is:

- lower on the left side than on the right side of the helicopter,
- lower to the sides of the flight path than directly underneath, and
- lower upwind than downwind of the helicopter.

Takeoff and Climb

After departing translational, climb to VI 55 knots instead of the recommended normal procedure of Vy.

Enroute and Cruise

When crossing noise-sensitive areas, limit airspeed to 133 knots.

Plan routes to keep noise-sensitive areas on the left side of the helicopter. If such areas are on the right of the aircraft, do not approach within 500 meters.

Where possible, maintain a minimum altitude of 1,000 feet above ground level.

Approach and Landing

The speed of approach should be just under 45 knots during the entire descent.

Plan the approach and landing to keep noise-sensitive areas to the left of the helicopter.

Avoid descending directly over noise-sensitive areas.

Comments

The speed of takeoff and of approach are different from those for standard procedures. They are not optimal for complications such as emergency engine failure, and do not comply with Category A flight procedures. In particular, the takeoff speed of 55 knots is recommended only for noise abatement. Pilots are expected to take into account gross weight and environmental conditions, and to use their judgment when applying this noise abatement procedure.

Agusta A109A, A109A II, and A109C

General

Maximum distance and altitude separation from noise-sensitive areas is the most effective means of noise abatement.

Control movement should be gradual and smooth.

Noise exposure is:

- lower behind than forward of the helicopter,
- lower on the left side than on the right side of the helicopter,
- lower to the sides of the flight path than directly underneath, and
- lower upwind than downwind of the helicopter.

Takeoff and Climb

Take off into the wind.

Climb at the best rate of climb in order to reach altitude as soon as possible.

Avoid a maximum power climb over noise-sensitive areas, when possible.

Enroute and Cruise

When crossing noise-sensitive areas, limit airspeed to 130 knots.

Plan routes to keep noise-sensitive areas on the left side of the helicopter.

Where possible, maintain a minimum altitude of 1,500 feet above ground level.

Approach and Landing

The speed of approach should be approximately 60 knots throughout the descent, until just before landing.

Use a steeper than normal approach—an angle of approximately 12-15° is best. This is almost the angle used for autorotation.

Do not increase the power until you are within 100 feet of the ground. Then flare and increase the power as for a normal landing.

Plan the approach and landing to keep noise-sensitive areas to the left of the helicopter.

Avoid descending directly over noise-sensitive areas.

Comments

Cruising speed for the Agusta is 140-150 knots, which falls within the requirements of ICAO Annex 16, Chapter 8 standards for inflight noise levels. Speeds below 130 knots are noticeably quieter to people on the ground.

The A109C model is generally quieter than previous models.

Bell (all models)

General

Ground-idle speeds are quieter than flight-idle speeds.

Low cruise speeds are quieter than maximum speeds.

Steeper takeoffs and landings are quieter than shallow ones.

Avoid long periods of hovering or flight-idle operations.

Avoid or minimize low-speed, near-hover flight high above a landing site.

Control movements should be gradual and smooth.

Takeoff and Climb

Take off at maximum power, maintaining best rate of climb.

Avoid takeoff flight paths directly over noise-sensitive areas or facilities.

Keep noise-sensitive areas or facilities to the inside of any turns.

Enroute and Cruise

Plan routes over high-ambient-noise surface transportation corridors.

Where possible, maintain a minimum altitude of 1000 feet over, and a lateral distance of 1000 feet from, noise-sensitive areas or facilities.

Approach and Landing

Plan the approach and landing to keep noise-sensitive areas or facilities to the left of the helicopter.

Start descent from 1000 feet at 10–15 kts faster air speed than usual.

Continually bleed off air speed during descent to maintain a comfortable descent rate.

Keep rotor torque as low as practicable and tune out the sound of the main rotor.

At the end of the approach, increase power and adjust ground speed for a normal landing.

Comments

Bell encourages pilots to become familiar with noise abatement procedures and to operate in a manner compatible with environmental concerns.

Classroom and flight instruction in noise abatement procedures is available from Bell Helicopter Textron, Inc. Customers Training Academy, 3000 S. Norwood, Hurst, Texas 76053. Telephone: (817) 280-4976

Boeing 234 and CH-47

General

Maximum distance and altitude separation from noise-sensitive areas is the most effective means of noise abatement.

Control movement should be gradual and smooth.

Noise exposure is:

- lower on the left side than on the right side of the helicopter,
- lower to the sides of the flight path than directly underneath, and
- lower upwind than downwind of the helicopter.

Takeoff and Climb

Plan takeoff path away from noise-sensitive areas.

Climb to cruise altitude at best rate of climb airspeed.

Enroute and Cruise

When crossing noise-sensitive areas, limit airspeed to 140 knots or Vne, whichever is less.

Use 98% RRPM in level flight.

Plan routes to keep noise-sensitive areas on the left side of the helicopter.

Where possible, maintain a minimum altitude of 1,000 feet above ground level.

Approach and Landing

Near noise-sensitive areas, use 85 knots as the minimum airspeed, and 1,000 fpm as the minimum rate of descent.

Plan the approach and landing to keep noise-sensitive areas forward and to the left of the helicopter.

Avoid descending directly over noise-sensitive areas.

Comments

The following procedures apply in general to Boeing models 107 and CH-46 as well, except that, for approach and landing, the 85 knots minimum airspeed and the 1,000 fpm minimum rate of descent has not been verified for these models, and the 140 knots cruising limit should be lower.

Enstrom F28F and 280FX

General	Maximum distance and altitude separation from noise-sensitive areas is the most effective means of noise abatement. Control movement should be gradual and smooth. Noise exposure is lower on the right side than on the left side of the helicopter.
Takeoff and Climb	Avoid a maximum power climb over noise-sensitive areas, when possible. Nominal main rotor speed for Enstrom aircraft is 350 rpm. Taking off at 334 rpm is quieter.
Enroute and Cruise	When crossing noise-sensitive areas, limit airspeed to 50–55 knots. Plan routes to keep noise-sensitive areas on the right side of the helicopter.
Approach and Landing	Avoid a maximum power descent over noise-sensitive areas, when possible. Nominal main rotor speed for Enstrom aircraft is 350 rpm. Descending at 334 rpm is quieter. Plan the approach and landing to keep noise-sensitive areas to the right of the helicopter. Avoid descending directly over noise-sensitive areas.
Comments	An optional muffler is available to decrease noise levels by approximately 4.5 dB.

MBB BK117 and BO105

General

Maximum distance and altitude separation from noise-sensitive areas is the most effective means of noise abatement.

Control movement should be gradual and smooth.

Make turns gradual and gentle, rather than steep.

Noise exposure is:

- lower on the right side than on the left side of the helicopter,
- lower to the sides of the flight path than directly underneath,
- lower in front of the helicopter than behind it, and
- lower upwind than downwind of the helicopter.

Takeoff and Climb

Plan takeoff path away from noise-sensitive areas.

Climb to cruise altitude at best rate of climb airspeed.

Do not hover after lift-off.

Enroute and Cruise

When crossing noise-sensitive areas, limit airspeed to 125 knots.

Plan routes to keep noise-sensitive areas on the right side of the helicopter.

Where possible, maintain a minimum altitude of 1,000 feet above ground level.

Approach and Landing

Near noise-sensitive areas, use a steep angle of descent—approximately 12-15°.

Land quickly after flaring; don't hover.

Plan the approach and landing to keep noise-sensitive areas forward and to the right of the helicopter.

Avoid descending directly over noise-sensitive areas.

Comments

The aircraft is noisiest while hovering, just after flaring immediately before a landing, and immediately after taking off. Therefore, minimize the time spent in these positions.

McDonnell Douglas (Hughes) MD500N, MD500D, and MD500E

General

Maximum distance and altitude separation from noise-sensitive areas is the most effective means of noise abatement.

Control movement should be gradual and smooth.

Noise exposure is:

- lower to the sides of the flight path than directly underneath, and
- lower upwind than downwind of the helicopter.

Takeoff and Climb

Plan takeoff path away from noise-sensitive areas.

Climb to cruise altitude at the best rate of climb airspeed—60–62 kts.

Use the maximum power for takeoff.

The MD500N is quieter on the right side than on the left.

The MD500D/E is quieter on the right side than on the left, when equipped with a four-bladed tail rotor. If the MD500D/E has a two-bladed tail rotor, noise exposure is the same to either side.

Enroute and Cruise

When crossing noise-sensitive areas, maintain airspeed of no more than 110 knots.

Where possible, maintain a minimum altitude of 1,000 feet above ground level.

Plan routes to keep noise-sensitive areas on the left side of the helicopter.

Turn as sharply as possible. Coordinated turns at approximately the speed for the best rate of climb cause no appreciable change in noise. Sharper turns reduce the area exposed to noise.

The MD500N is quieter on the right side than on the left.

The MD500D/E is quieter on the right side than on the left, when equipped with a two-bladed tail rotor.

The MD500D/E is quieter on the left side than on the right, when equipped with a four-bladed tail rotor.

Approach and Landing

Near noise-sensitive areas, use the steepest glide slope consistent with passenger comfort and safety.

Plan the approach and landing to keep noise-sensitive areas to the left of the helicopter.

Avoid descending directly over noise-sensitive areas.

The MD500N is quieter on the right side than on the left.

The MD500D/E is quieter on the right side than on the left, when equipped with either tail rotor.

Comments

The MD500D/E is noticeably quieter when equipped with the four-bladed tail rotor (369D2925000). The MD500N is quieter than either of the other aircraft.

Robinson R22

General

Maximum distance and altitude separation from noise-sensitive areas is the most effective means of noise abatement.

Control movement should be gradual and smooth.

Noise exposure is:

- lower on the right at high power settings, and
- lower forward and on the left when hovering.

Takeoff and Climb

Accelerate to 60 knots as quickly as possible.

Climb at a high rate of climb in order to reach altitude as soon as possible.

Enroute and Cruise

When possible, maintain a minimum altitude of 500 feet above ground level.

Approach and Landing

Near noise-sensitive areas, use 60 knots as the minimum airspeed.

Use a steep approach.

Comments

Avoid blade slap when flying over noise-sensitive areas.

Rogerson Hiller UH12 and RH1100

General	Maximum distance and altitude separation from noise-sensitive areas is the most effective means of noise abatement. Control movement should be gradual and smooth. Noise exposure is lower in front of than behind the helicopters.
Takeoff and Climb	Avoid a maximum power climb over noise-sensitive areas, when possible.
Enroute and Cruise	Where possible, maintain a minimum altitude of 500 feet above ground level.
Approach and Landing	Approach with forward speed—avoid hovering during approach and descent. Avoid a maximum power descent over noise-sensitive areas, when possible.
Comments	Optional mufflers are available.

Schweizer 300C

General

Maximum distance and altitude separation from noise-sensitive areas is the most effective means of noise abatement.

Control movement should be gradual and smooth.

Noise exposure is:

- lower in front of than behind the aircraft,
- lower on the right during takeoff and climbing, and
- lower on the left during approach and landing.

Takeoff and Climb

Avoid a maximum power climb over noise-sensitive areas, when possible.

Plan the takeoff and climb to keep noise-sensitive areas to the right and in front of the helicopter.

Enroute and Cruise

Normal cruising speed for the aircraft is 65–70 knots. When crossing noise-sensitive areas, limit airspeed to 55–60 knots.

Approach and Landing

Avoid a maximum power descent over noise-sensitive areas, when possible.

Plan the approach and landing to keep noise-sensitive areas to the left and in front of the helicopter.

Comments

An optional quieting kit is available to decrease noise levels. This kit (part number 269A8245–800) consists of a resonator for the muffler and a dual scale tachometer. The resonator decreases muffler noise and directs it upward. The tachometer indicates an additional green range for flying the helicopter under a low-noise regime. Under this regime, certain flight limitations apply. Observe the information in the flight manual supplement.

Sikorsky S-76A

General

Maximum distance and altitude separation from noise-sensitive areas is the most effective means of noise abatement.

Control movement should be gradual and smooth.

Noise exposure is:

- lower on the right side than on the left side of the helicopter, and
- lower upwind than downwind of the helicopter.

Takeoff and Climb

Plan takeoff path away from noise-sensitive areas.

Climb to cruise altitude at the best rate of climb airspeed.

Adjust the power to maintain a 1300 fpm rate of climb.

Enroute and Cruise

When crossing noise-sensitive areas, maintain a minimum altitude of 2,000 feet.

When an altitude of 2000 feet cannot be maintained, reduce airspeed so as not to exceed 120 knots at 500 ft.

Plan routes to keep noise-sensitive areas on the right side of the helicopter and on the inside of a turn.

Turns

Noise exposure is:

- lower on the inside of a turn than on the outside of the turn,
- lower during right turns than left turns.

Make hovering turns so that the tail of the helicopter points away from the noise-sensitive area, when practical.

Approach and Landing

For greatest noise reduction, establish a 60 knots indicated air speed and 1000 fpm rate of descent.

If you wish a moderated approach angle, use 80 knots and 800 fpm rate of descent.

When clear of the noise-sensitive area, return to Category A or Category B flight procedures, as applicable.

Plan routes to keep noise-sensitive areas on the right side of the helicopter and on the inside of a turn.

Avoid descending directly over noise-sensitive areas.

Westland 30

General

Maximum distance and altitude separation from noise-sensitive areas is the most effective means of noise abatement.

Control movement should be gradual and smooth.

Minimize hover and low speed flight whenever practicable, as these are particularly noisy conditions.

Noise exposure is lower upwind than downwind of the helicopter.

Impulsive main rotor noise, which often gives rise to complaints, cannot always be detected from inside the cockpit. Therefore, use observers on the ground to supplement pilots' views when developing procedures for specific heliports or airports.

Ground Running and Taxiing

Minimize the time spent running and taxiing on the ground.

During prolonged ground running at minimum power, it is recommended that the engine control levers are retarded sufficiently for an rotor speed of 90%.

Takeoff and Climb

Plan takeoff path away from noise-sensitive areas.

Climb to cruise altitude at the best rate of climb airspeed.

Avoid banked turns on takeoff.

Enroute Cruise and Descent

Maintain a minimum altitude of 1500 feet over urban areas.

Maintain a minimum altitude of 2500 feet over noise-sensitive suburban or rural areas.

When these altitudes cannot be maintained, reduce airspeed so as not to exceed 110 knots.

When descending enroute, maintain airspeed above 100 knots, and keep descent rate below 500 fpm.

Turns

When possible, turn at a constant altitude; avoid descending turns.

If descending turns are unavoidable, maintain an airspeed above 80 knots.

If a rapid turn is required, keep noise-sensitive areas inside the turn.

Approach and Landing

Avoid descending directly over noise-sensitive areas.

Reduce airspeed to 110 knots before beginning descent.

Initial Approach:

Gradually establish a high rate of descent—approximately 1250 fpm. Maintain a high forward speed (approximately 100 knots indicated airspeed). This corresponds to an approximate approach angle of 7 degrees.

If a lower rate of descent is desirable, use 80 knots indicated airspeed and 1000 fpm. The actual values can be modified by flight envelope limitations.

Maintain the approach condition for as long as compatible with meeting the final approach requirement to pass through the decision height (landing decision point).

Final Approach:

Attain a rate of descent compatible with meeting the decision height requirements of not more than 750 fpm rate of descent and 60 knots indicated airspeed. The rate of descent at the decision height should be kept low, when practical, to minimize noise in the landing transition.

Thereafter gradually reduce airspeed and rate of descent to that required for the landing procedure.

Operator Program

Introduction

The Fly Neighborly program attacks the problem of helicopter noise on three fronts: pilot training, flight operations planning, and public education and acceptance. These three areas are interrelated: planning flight operations with an eye to noise abatement can have a major positive impact on both the pilot training program, and public acceptance.

The information presented in this section provides only a broad outline of the possible actions helicopter operators can take. Operators are encouraged to expand this outline by applying knowledge of their own geographical area of operations, the nature of their businesses, and the local climate of opinion with regard to helicopter operations.

Company Policy

Implement a company policy aimed at reducing the sound levels produced by the operation of your aircraft or other equipment. As part of this policy, implement a broad-based complaint prevention program. Such a voluntary program is necessary to preclude the eventual implementation of restrictive and mandatory federal, state, or local laws, regulations, or ordinances.

To formulate this policy, identify and evaluate current and possible future problems. To assure its acceptance and success, make your commitment to your policy clear, in order to generate such change as may be necessary in the attitudes' of pilots and other personnel.

Company Operations

In order for company policy to have any meaning, companies should formulate and implement specific guidelines.

Formulate Guidelines

Guidelines are intended to assist flight crews and flight operations personnel to formulate responsible mission profiles without infringing on operational reality. They are not, however, provided as a substitute for good judgment on the part of the pilot. They must also not conflict with federal aviation regulations, air traffic control instructions, or aircraft operating limitations. The noise abatement procedures outlined by these guideline should be used when consistent with prudent and necessary mission requirements. The safe conduct of flight and ground operations remains the primary responsibility.

- Enroute operations:
  - Maintain an altitude of 1000 feet above ground level or higher when possible. Complaints are significantly reduced when operating above this level. The reverse is also true.
  - Vary routes in order to disperse the aircraft sound.
- Terminal operations:
  - Restrict hours or frequency of operations as appropriate. Minimize early or late flights on holidays and weekends.
  - Limit ground idling in noise-sensitive areas.
  - Minimize flashing landing lights in residential areas at night.
- Establish procedures for each sensitive route or terminal.
- Provide flight crews with noise abatement procedures for each model of aircraft.

Implement Guidelines

- Publish all guidelines and procedures in a flight operations manual or similar document.
- Train flight crews and flight operations personnel as appropriate:
  - Indoctrinate with basic attitudes in ground school.
  - Train in noise abatement procedures for each model of aircraft to be flown.
  - Emphasize awareness and recognition of sensitive routes and terminals.
  - Establish a requirement that noise abatement procedures must be considered in recurrent company flight checks.
- Assign responsibility and authority for the company program to an appropriate person.

Review and Revise

Establish periodic reviews of company policy and programs to respond to changes in the regulatory climate or operational conditions. Revise your policy and programs as necessary.

Public Acceptance

Scope

The scope of the public acceptance program includes:

- engendering media support,
- promoting positive public relations, and
- enacting a program to prevent or resolve complaints from the public.

Media Support

The purposes of engendering media support are to:

- develop favorable and active helicopter-related media coverage, and
- provide valid information concerning helicopter operations as necessary.

Media sometimes concerned with news of helicopter-related activities include general circulation newspapers, television and radio news, trade journals, and the magazines or newsletters of international, national, state, and regional helicopter associations.

To engender awareness and support in these media, you can take a number of actions:

- Provide press releases to trade journals and local newspaper, radio, and television news editors concerning any Fly Neighborly seminars that your local branch of the Fly Neighborly Committee may sponsor.
- Support a continuing campaign with the trade journals to keep the rotary-wing community aware of the Fly Neighborly program.
- Support a continuing campaign with the general press to make the public aware of the Fly Neighborly program, and the benefits of helicopter transport.
- Stage demonstrations and press conferences addressing specific local issues such as heliports, high-rise evacuation, police services, search and rescue services, emergency medical evacuation, fire-fighting, and the benefits of helicopter transportation to the general public.

Public Relations

The purposes of engaging in public relations activities are to:

- develop awareness in the community of the benefits of helicopter transportation,
- develop awareness of the Fly Neighborly program, and
- develop support for the voluntary Fly Neighborly program, as administered by the helicopter community, in lieu of governmental regulation.

In order of their general importance and effectiveness, public relations activities can be undertaken in conjunction with:

- governmental agencies concerned with aviation such as federal, state, or local agencies, the FAA, or state aeronautics commissions;
- other governmental agencies not particularly concerned with aviation, such as regional planning commissions, economic development commissions, the National League of Cities, or the U.S. Council of Mayors;
- service clubs and professional organizations such as local Rotary or Kiwanis Clubs, the National Association of Aviation Officials, the Airport Operators Council International, or the National Fire Protection Association;
- nongovernmental economic development agencies such as chambers of commerce, regional economic development councils, or merchant associations;
- direct public contact;
- environmental organizations such as Greenpeace, the Sierra Club, or federal or state environmental protection agencies; and
- local civic organizations.

You can improve public relations by influencing government agencies concerned with aviation in the following ways:

- Participate in public hearings.
- Provide professional testimony as appropriate.
- Conduct flight demonstrations.
- Conduct one-on-one campaigns.
- Submit petitions and letters.

Place speakers on the agendas of national and international meetings and conferences of government agencies not especially concerned with aviation.

Place speakers at local meetings of service clubs and professional organizations. Solicit their sponsorship of heliports based on the Fly Neighborly program as civic projects to promote public service.

Demonstrate to economic development agencies how helicopter transportation benefits the community, and present data to show the economic viability of helicopter transportation.

Provide information to environmental organizations. Do not immediately assume they are hostile to your operations. Instead, emphasize the positive environmental aspects of helicopter operations, such as the fact that they are involved in search and rescue operations for hikers or workers injured in remote areas, and that they provide access to such areas without the need to pave over ground for landing strips.

Provide speakers to civic organizations to provide information about helicopter operations. Contact them to promote support for heliport development efforts.

In many cases, you can contact the public directly to promote helicopter operations. If you are conducting a Fly Neighborly seminar or an industry display, open it to the public when feasible. Provide displays and demonstrations in such public areas as local shopping malls. Provide the occasional courtesy ride when possible. And finally, do not neglect the opportunity to buttonhole social or professional contacts in your local community to counter misinformation or build support.

Preventing and Responding to Complaints

Helicopter operations are undeniably noisy, and the bulk of this manual is concerned with techniques designed to minimize the problem. The following figure shows the relationship between how much noise people are exposed to, and how annoyed they are likely to get.

Helicopter operators can do a bit more to prevent noise complaints, and the section below details how. However, even the best-run operations will get some complaints, and the section that follows will provide some guidelines for how to respond.

Complaint Prevention

A significant number of noise-related complaints can be prevented in the first place, given a certain degree of sensitivity, foresight, and commitment on your part.

Prevent complaints by assessing the environmental compatibility of potential landing facilities. Select those most suitable from a safety, operational, and environmental point of view.

Implement a public acceptance program.

- When contemplating site licensing, identify, contact, and try to influence potential sources of opposition before the hearing.
- Initiate or support presentations, seminars, or displays to educate the public about the value of helicopter transport.

Educate your customers about noise abatement procedures, in order to prevent or minimize conflicts between their expectations and company policy.

Coordinate operations personnel and flight crews, so that flights that would unnecessarily violate company policy are not assigned.

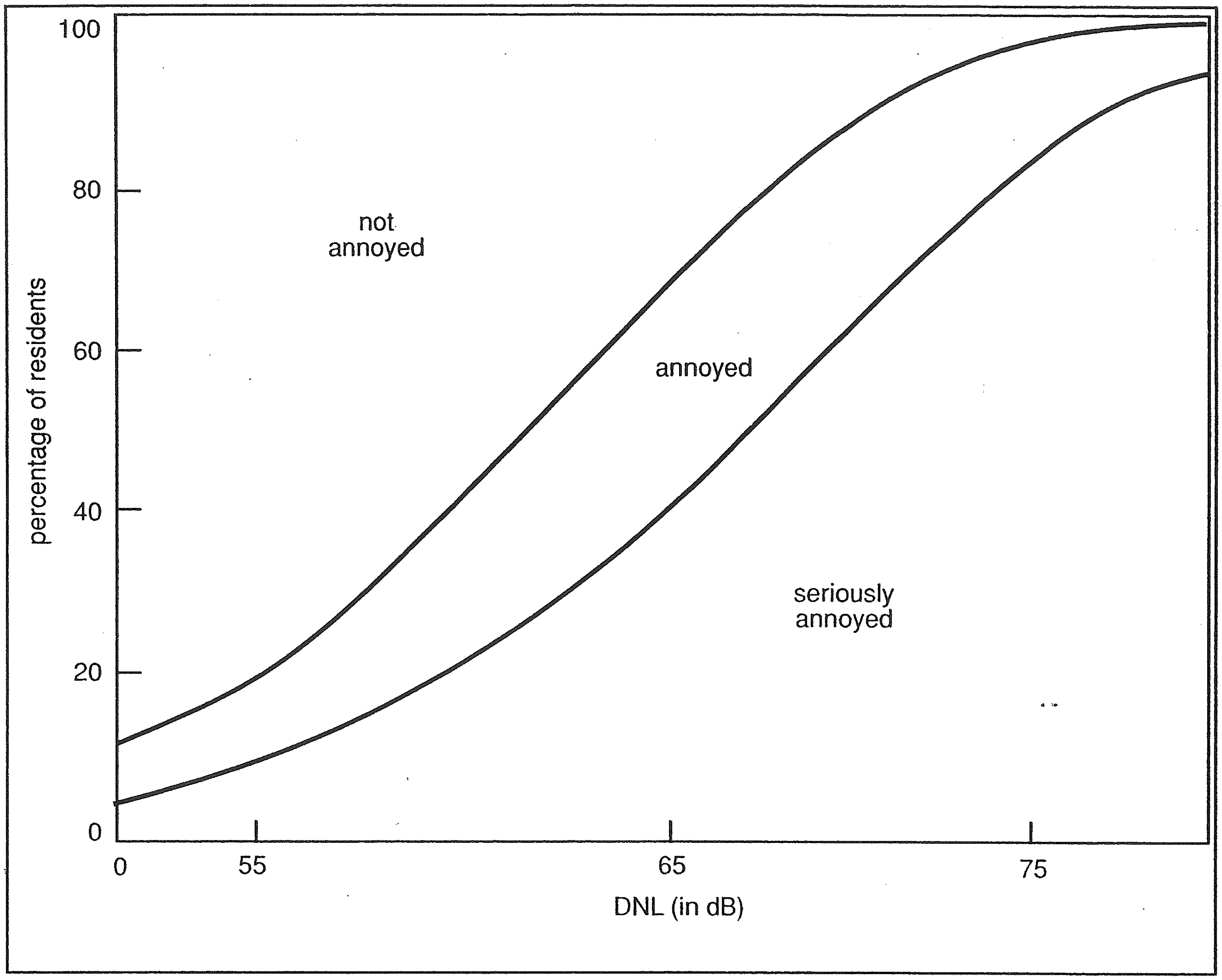

Figure 4. *Relationship Between Noise Exposure and Annoyance*

Handling Noise Complaints

Although earlier sections of this manual offer information concerning noise-abatement techniques, it is unlikely that you will be able to avoid all noise complaints. Because some complaints are inevitable, how you handle such complaints is also important to the success of the Fly Neighborly program.

When someone complains about a noisy overflight by a fixed-wing aircraft, it is often because the pilot has violated FAA regulations. However, helicopter-generated complaints can result even when no FAA regulations have been violated. A helicopter can annoy people on the ground while it is well above the prescribed altitude minimums.

The resulting problem is not simple. If someone calls the FAA or a state agency and offers routine information such as the aircraft registration number, colors, or type, it is likely that he or she will be told that the aircraft was not in violation of any regulation, and that therefore nothing can be done. If callers are not able to offer routine information, chances are they will be told nothing can be done even if a violation has occurred. In either case, the results are the same: an angry, frustrated member of the community will probably not be particularly supportive of any current or future helicopter- or heliport-related issues.

The helicopter user community has a real, financial interest in assuring that all complaints are appropriately addressed. Conventional channels for complaints are demonstrably insufficient. Therefore, a number of regional helicopter associations have started to operate their own complaint lines. These lines offer state, federal and local agencies another option when they receive complaint calls about legal and proper operations. The agencies can pass the complaint along to the regional association, or provide the complainant with the telephone number of the complaint line. The complaint line can then listen to the caller and determine what, if anything, can be done.

Such programs offer a number of benefits:

- Regional associations can often identify an aircraft with much less information than other agencies require.
- Associations can ensure that each issue is addressed and, when possible, satisfy the complainant.

The back of this handbook lists addresses and phone numbers of the various regional affiliates of HAI. You may wish to contact your local affiliate to see if a helicopter noise complaint line is currently available in your area.

If you receive such a complaint, how can you address it?

1. The most effective way to deal with the complaint is to contact the complaining party personally. When you do, avoid being defensive, argumentative, or opinionated. Try sincerely to understand the other person's point of view, and avoid hostile confrontations. Sometimes merely listening politely can improve the situation.
2. Furthermore, evaluate the problem thoroughly, and follow through. Was the pilot aware of the problem? Was there something the pilot could have done to avoid it? Is it likely to recur? Contact the pilot or the operator to determine the facts. Consult this guide, and other sources of noise-abatement information, to determine how best to improve the situation.
3. Finally, respond sincerely to the caller. Tell him or her what you learned, and what is being done to avoid the situation next time.

Of course, the best way to handle complaints is to avoid them in the first place. If you can anticipate a problem with a certain operation, contact the likely complainant before the operation begins. Explain to him or her the purpose, timing, and duration of the operation, and its likely impact upon the area. People like to feel that they have some control over their lives; often just a simple courtesy call in the beginning can save you hours of trouble and nuisance later.

The section below provides one example of noise-related problems resulting from the establishment of a heliport in a downtown area, and the noise-abatement program that was put into effect to improve the situation.

An Example: The Portland Public Heliport Noise Abatement Program

In 1989, the city of Portland, Oregon and the Northwest Rotorcraft Association decided to build a heliport to provide direct air access to downtown Portland. During hearings to approve the facility, concern was expressed about the resulting noise increase in the area surrounding the heliport. In response to this concern, the following noise abatement program was put into effect.

Noise Abatement

Pilots are requested to utilize the following noise abatement procedures whenever possible. Of course, it is the pilot's responsibility on each flight to determine the actual piloting techniques necessary to maintain safe flight operations.

1. *Flight Paths:* Maintain approach and departure paths over river and freeways. Avoid residential neighborhoods, the McCormick Pier Apartments, the convention center towers, and the piers for the Steel Bridge. Approach and depart over the Morrison, Broadway, and Grand Avenue bridges. [A map is provided with those features marked.]
2. *Steep Departure:* Depart at Vy (best rate of climb) when possible.
3. *Steep Approach:* Use steep approach angle when possible (PLASI is set for a 10° approach).
4. *Night Operations:* Avoid night approach from the north, as it passes near the McCormick Pier Apartments.
5. *Minimize Ground Operations:* Minimize the duration of warm-up or cool-down periods (typically two to three minutes). Do not idle at the heliport for prolonged periods.
6. *Avoid High Noise Regime:* Most helicopters have a high noise regime near a descent profile of 70 knots at 300 fpm. [Figures 7, 8, and 9] from Bell Helicopters indicate the extent of this high noise regime. Pilots can avoid descent through this area by initiating the descent at a higher speed than normal.
7. *Gradual and Smooth Control Inputs:* Gradual and smooth control inputs result in reduced noise impact.
8. *Avoid Steep Turns:* Avoidance of steep turns results in reduced noise impact.
9. *Enroute Altitude:* Whenever possible maintain 2000 feet above ground level over residential neighborhoods and other noise-sensitive properties, as per FAA AC 91-36 "VFR Flight Near Noise-Sensitive Areas."

10. *Fly Neighborly:* Refer to the HAI Fly Neighborly program for additional information on how to minimize helicopter noise impact.

    Citizen concerns about helicopter noise emanating from the Portland Heliport should be brought to the attention of the Northwest Rotorcraft Association by calling 286-0927. All noise complaint calls will be logged. If the caller can identify the helicopter involved, follow-up calls will be made to the involved helicopter pilot and then back to the concerned citizen.

    The Bureau of General Services maintains a Portland Heliport Noise Abatement Committee. When noise issues at the heliport cannot be easily resolved, the committee will be convened to assist in the resolution process, and the logs reviewed for pertinent information.

    As concerns noise abatement of helicopter traffic in other parts of the city, it is noted that the Port of Portland has developed a plan of preferred helicopter flight routes for use in the greater Portland metropolitan area, especially as concerns helicopter traffic to and from Portland International Airport and Portland Hillsboro Airport.

Appendix A: About Helicopter Noise

Introduction

This section describes the source of helicopter noise and how it is affected by the weather. It also provides reference information on the noise certification procedures for helicopters, and charts showing the takeoff, flyover, and approach noise levels for a variety of helicopter models.

The following section was written by Charles Cox, a research project engineer with Bell Helicopter. In it, he explains the causes of helicopter noise. Although the information offered by Mr. Cox may be somewhat specific to Bell helicopters, the general information he offers applies to the operation of all helicopters.

Helicopter Noise

When you start operating a helicopter in new territory, you add a new spectrum of sound to the usual noise environment. If that territory is a municipality, thousands of people will hear the new sounds and know where they are coming from. How they react depends upon physical, economic, and psychological factors, but one thing is certain: they will react strongly, adversely, and actively if the sound is too irritating, if it represents something that seems to threaten their safety and well-being, or if they cannot see how the noisemaker benefits them. Although it is up to operators to educate the public about the safety and usefulness of the helicopter—and to equip the aircraft with sound-suppressing devices when these are available and necessary—pilots can make the public less hostile to the helicopter (and to the operator's arguments about its safety and community service) by flying in such a way as to make the sound of the aircraft as unintrusive as possible.

Figures 5 and 6 show helicopter noise levels, and illustrate where helicopters of various weights fit into the overall noise picture. The units of the vertical scale represent, to some extent, the degree to which a sound annoys an average human listener. We cannot say what sound level will make an individual complain to the authorities. Instead, we show on the figures the sound level of a diesel locomotive and a truck or motorcycle. You can compare this with the sound of the helicopter and draw your own conclusions.

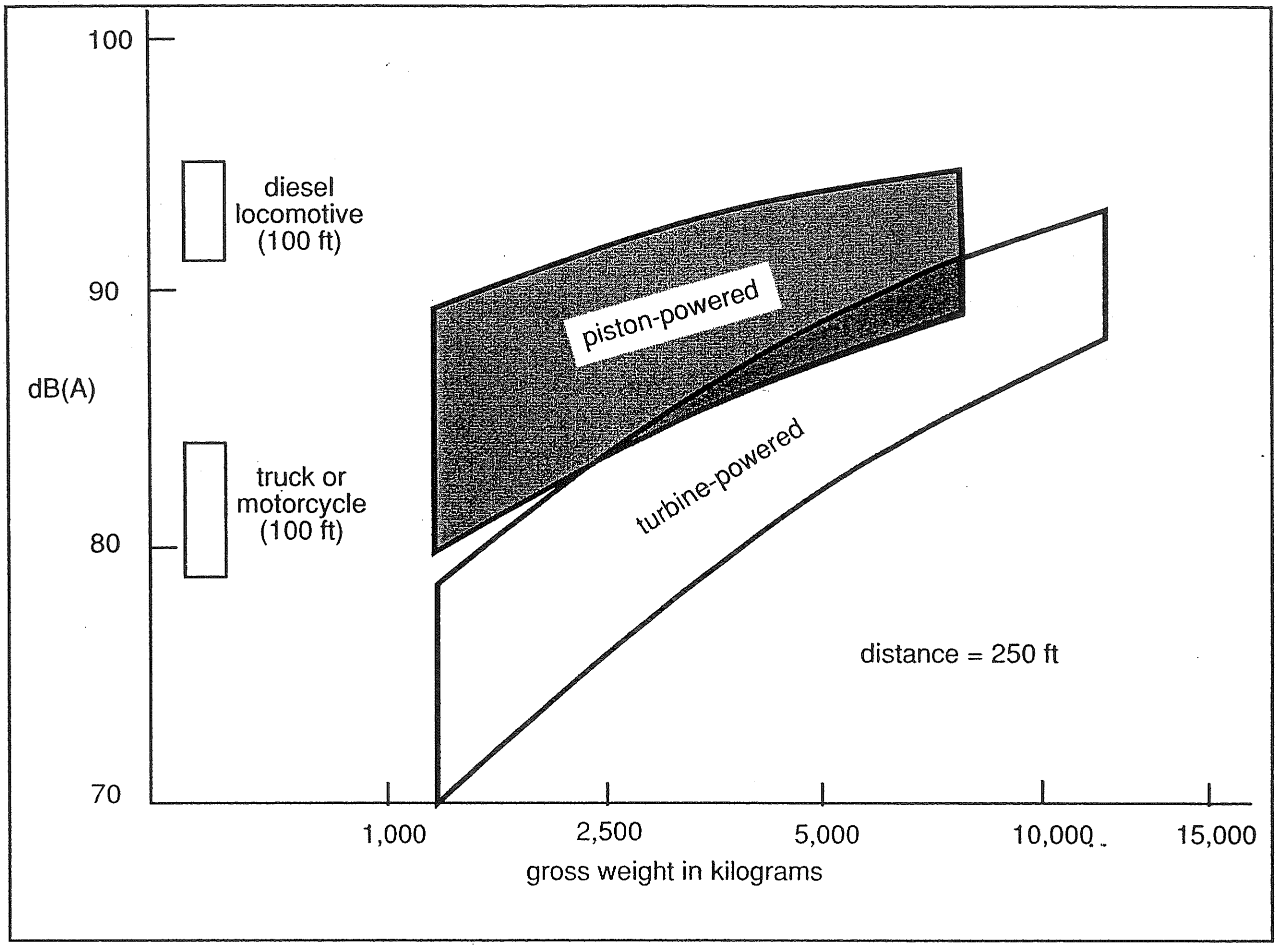

Figure 5. *Helicopter Noise Levels in dB(A) Units*

Notice that the noise level of a helicopter is a function of the type of power plant. Turbine-powered helicopters are quieter than piston-powered ones with unmuffled engine exhausts, and produce sounds no louder than those of familiar surface transportation vehicles.

Notice also that the noise level of a helicopter at a given gross weight covers a range. This is true not only for helicopters in general, but also for a particular helicopter—the particular one you may find yourself flying, for example. What pilots need to know is how to fly a helicopter, given a certain gross weight, in the lower portion of this range of sound levels—at least when you are flying near people whom noise might bother. This section discusses the conditions that produce higher noise levels during the operation of light turbine-powered helicopters such as the Bell Model 206A, or medium turbine-powered helicopters such as Bell Models 204B, 205A, and 212, and describes flight techniques that can help you avoid them. It also discusses methods to muffle the sound of light piston-powered helicopters such as the Bell Model 47.

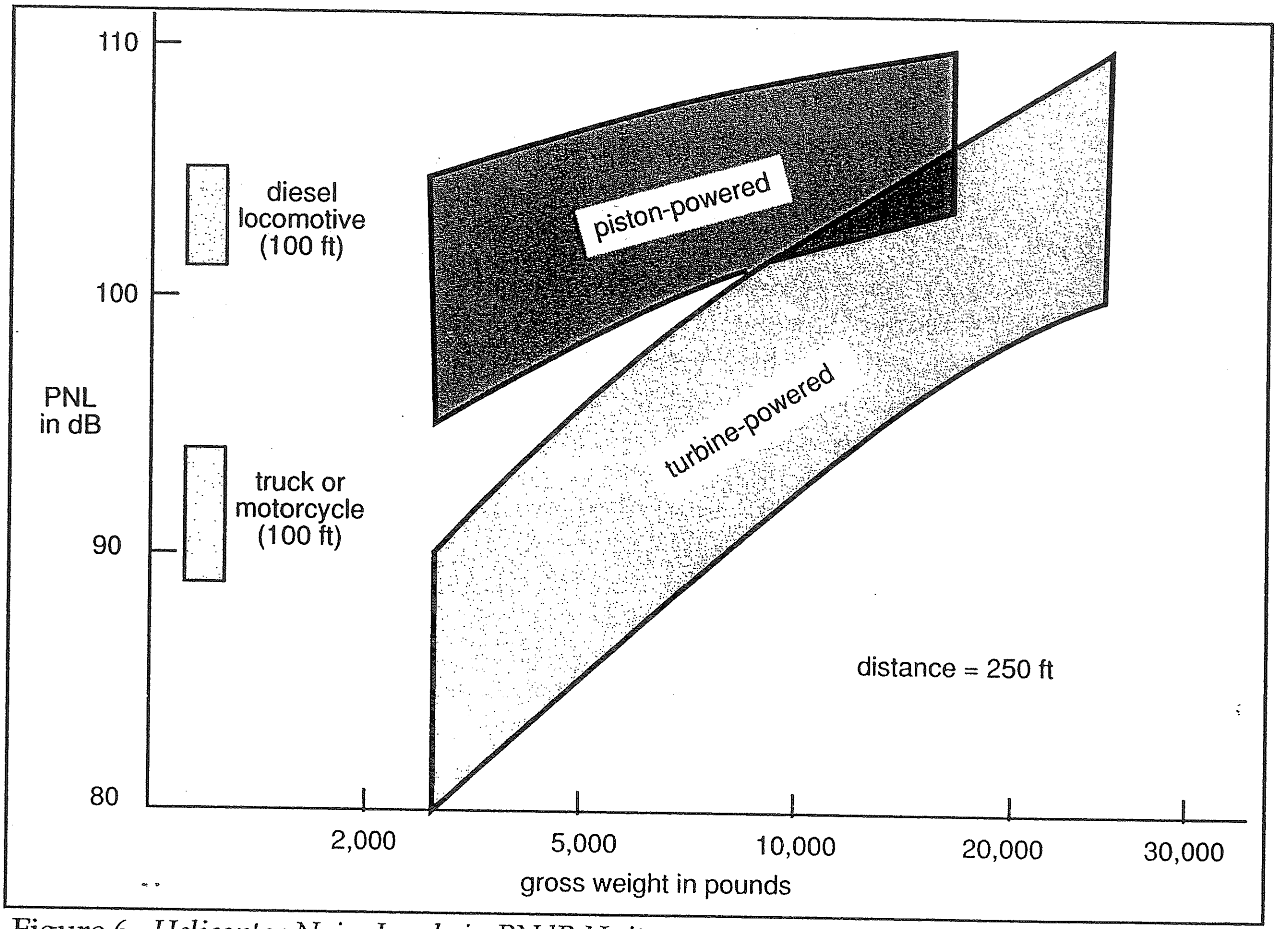

Figure 6. *Helicopter Noise Levels in PNdB Units*

The following discussion distinguishes between light and medium helicopters. *Light* helicopters are defined to be those helicopters weighing 5000 pounds gross, or less. *Medium* helicopters are defined to be those helicopters weighing 5000 to 12,000 pounds gross.

The Source of the Sound

The acoustical signature of a helicopter is partly due to the modulation of sound by the relatively slow-turning main rotor. This modulation attracts attention, much as a flashing light is more conspicuous than a steady one. The modulated sound is often referred to as *blade slap*.

For a typical medium helicopter, blade slap occurs during high-speed forward flight when a main rotor blade enters the compressible-flow region on the side of the advancing blade. The blade's airloads fluctuate, often quite rapidly. These fluctuations cause shock waves that generate noise. This typically occurs at airspeeds above about 100 knots.

At lower speeds, or for a typical light helicopter, blade slap occurs when a blade intersects its own vortex system or that of another blade. When this happens, the blade experiences locally high velocities and rapid angle-of-attack changes. This can momentarily drive a portion of the blade into compressibility and possibly shock stall, both of which produce aerodynamic loading variations. Either or both mechanisms generate sound.

For a typical light helicopter, the mechanisms described above occur during partial power descents. For a typical medium helicopter, they can occur in low-speed level flight, during partial power descents, or in turns.

Figure 7, a chart of blade slap regions as functions of airspeed, rate of climb (R/C), and rate of descent (R/D), shows the conditions under which you can expect the Model 206A to produce this sound. As you can see, maximum blade slap occurs at airspeeds between 75 and 95 mph, and rates-of-descent between 300 and 600 fpm. The *slap boundary* for your particular helicopter may be somewhat larger than that shown, because the main rotor may slap intermittently when it encounters wind gusts, or during a rapid transition from one flight condition to another. Although the sound produced at these descent rates is not extremely loud to crew members inside the helicopter, they can ordinarily recognize it, and thereby define the slap boundaries for their particular helicopter. Of course, people on the ground hear the blade slap grow more intense as the helicopter descends.

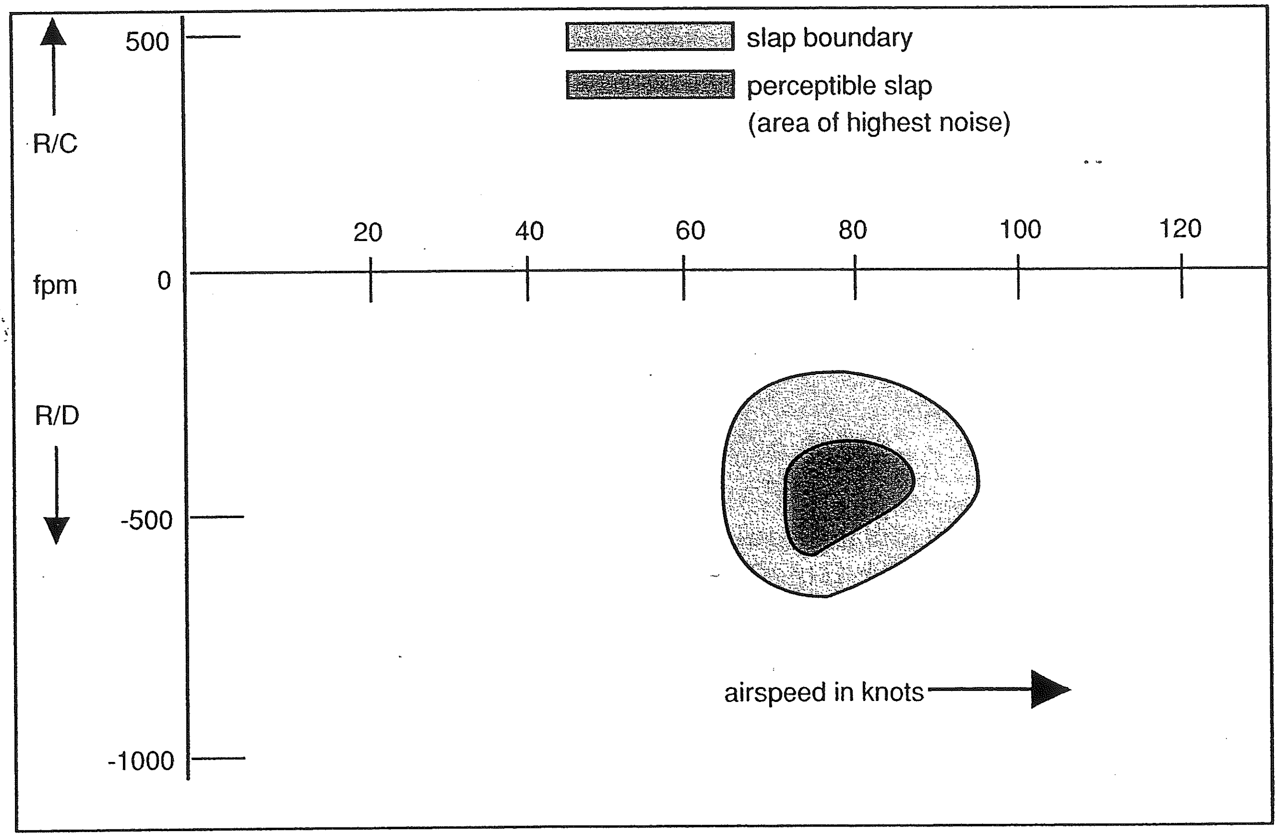

Figure 7. *Noisy Flight Operations—Light Helicopters*

Figures 8 and 9 show the conditions under which you can expect Models 204B, 205A, and 212 to get noisy, giving blade slap regions as functions of airspeed, rate-of-climb (R/C), rate-of-descent (R/D), and *g* loading during turns.

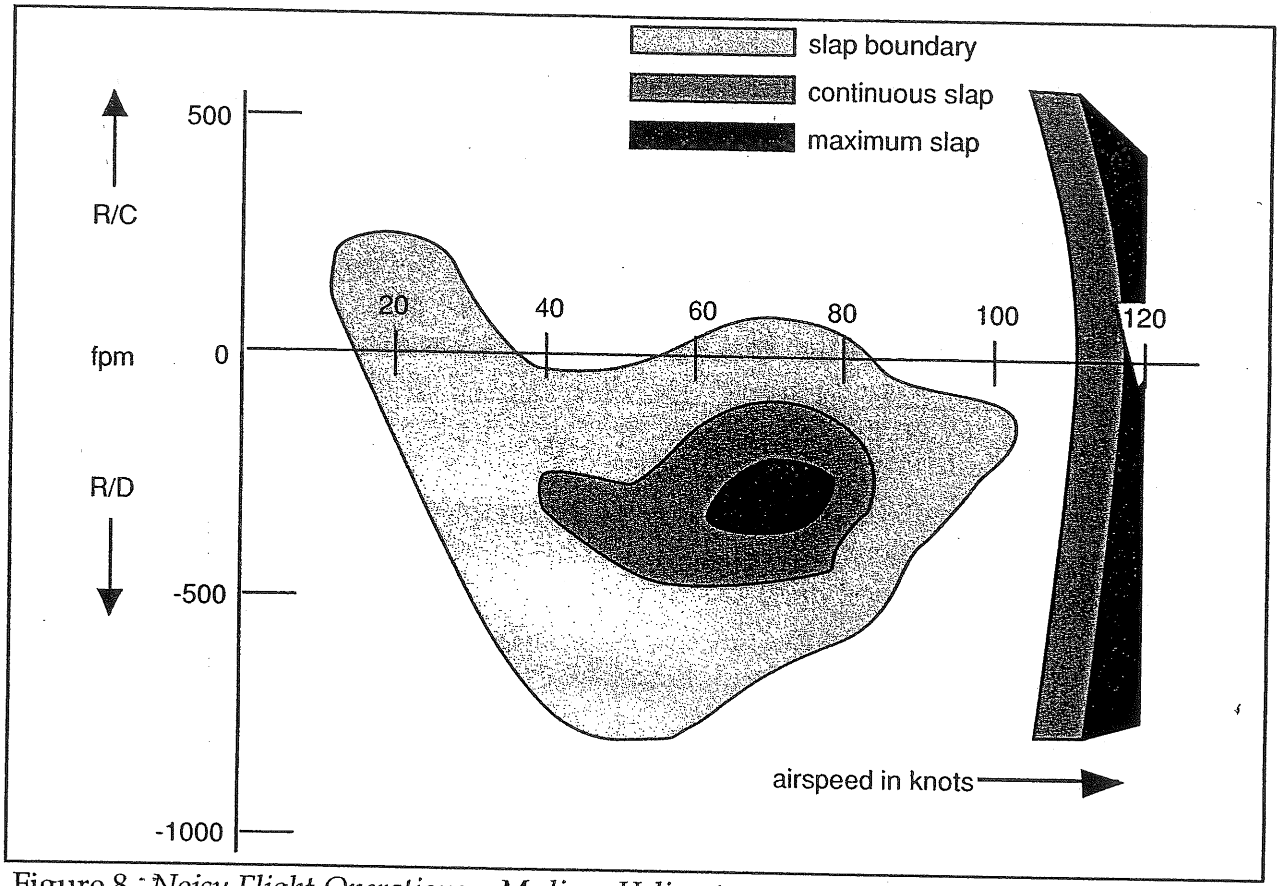

Figure 8. *Noisy Flight Operations—Medium Helicopters*

In general, the flight conditions described below are associated with more noise than normal for medium helicopters.

Low-Speed Level Flight and Partial Power Descents

In low-speed level flight, the main rotor slaps to some degree at airspeeds between 10 and about 85 knots. The worst condition is approximately between 60 and 80 knots, at these speeds the rotor slaps almost continuously. At other airspeeds it slaps intermittently, an action that can be triggered by wind gusts and by transitions from slight climbs to descents.

Maximum blade slap occurs during partial power descents, at airspeeds between 60 and 80 knots and rates of descent between 200 and 400 fpm. Engine torque pressure usually varies from 10 to 25 psi. This blade slap is caused by the blade interacting with the wake. Although the noise produced at these descent rates is not extremely loud to crew members inside the helicopter, they can usually recognize it and define the slap boundaries for their particular helicopter. Of course, people on the ground hear the blade slap grow more intense as the helicopter descends.

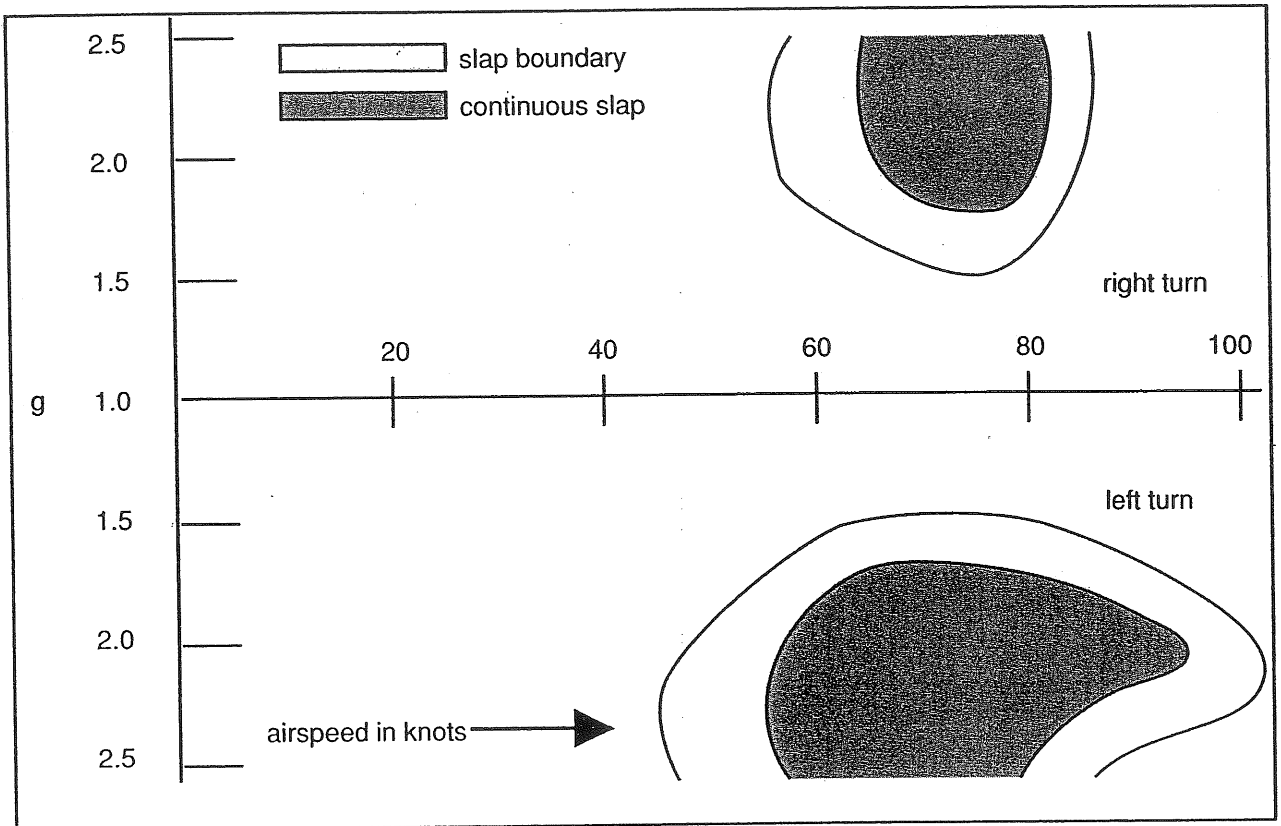

Figure 9. *Noisy Maneuvers—Medium Helicopters*

Cruise Airspeeds

At airspeeds above about 100 knots, blade slap intensifies; at these speeds, it sounds louder to people on the ground than it does during any other flight condition of the medium helicopter. Unfortunately, the crew members do not hear it that way, because this blade slap propagates primarily forward of the helicopter instead of spreading spherically.

Maneuvers

Blade slap also occurs during constant speed turns if turn rates are too high. Here the main rotor blade and wake interact in much the same manner as in partial power descents. As Figure 9 shows, continuous blade slap occurs in turns that exceed 1.5*g*, with airspeeds between 50 and 90 knots in a left turn, and between 40 and 110 knots in a right turn. There is little difference in the intensity of the noise in right or left turns once the critical *g* is reached. The crew can easily hear this sound.

Muffling

The engine noise of the piston-powered helicopter may be its loudest or most annoying sound, especially if the pilot uses the noise-abatement flight techniques to reduce blade slap. The best way to reduce the amount of sound coming from a piston engine is to install a muffler. Mufflers, however, impose penalties on the helicopter and increase its operating cost. The question then becomes one of how little muffling (how small a penalty) makes the helicopter socially acceptable for a given operation. This depends on how close to populated areas the helicopter must fly, the background noise levels in those areas, and how sensitive they are to noise. Figure 10 shows the intensities of various background noise generators, and the range of sound intensities emanating from piston-powered helicopters.

Naturally, you will want to use the lightest, cheapest muffler that will keep you out of trouble. If the operations are in remote, sparsely populated areas, or in areas of medium to heavy surface traffic, a muffler is probably unnecessary. If unmuffled operations bring sporadic complaints, then you will want a light muffler—perhaps one that can be installed and removed easily, and used only on those missions which take the helicopter close to sensitive areas. Operations in densely populated residential districts or which occur during the quiet hours of the night may require heavy muffling.

A light muffler can be mounted directly on the exhaust stacks. It reduces noise by an order of magnitude, while penalizing the performance of the helicopter only slightly. It removes the objectionable barking sound characteristic of unmuffled piston engines.

A larger muffler must be mounted on the fuselage structure because the exhaust stacks cannot support it; there may not always be room for it on the stacks, anyway. Flexible metal hoses connect the muffler to the exhaust stacks. Its mounts can be so designed that they will accommodate any one of a number of different mufflers, each to quiet the engine to a different level (and penalize it correspondingly).

As of this writing, several mufflers are available for piston-powered helicopters. (For example, Bell has a stack-mounted muffler available as a kit for the Model 47.)

As you run into more and more strenuous objections to noise, look to mufflers as part of the answer. Helicopter manufacturers and independent companies have continuing programs to produce mufflers that will keep you in your neighbors' good graces.

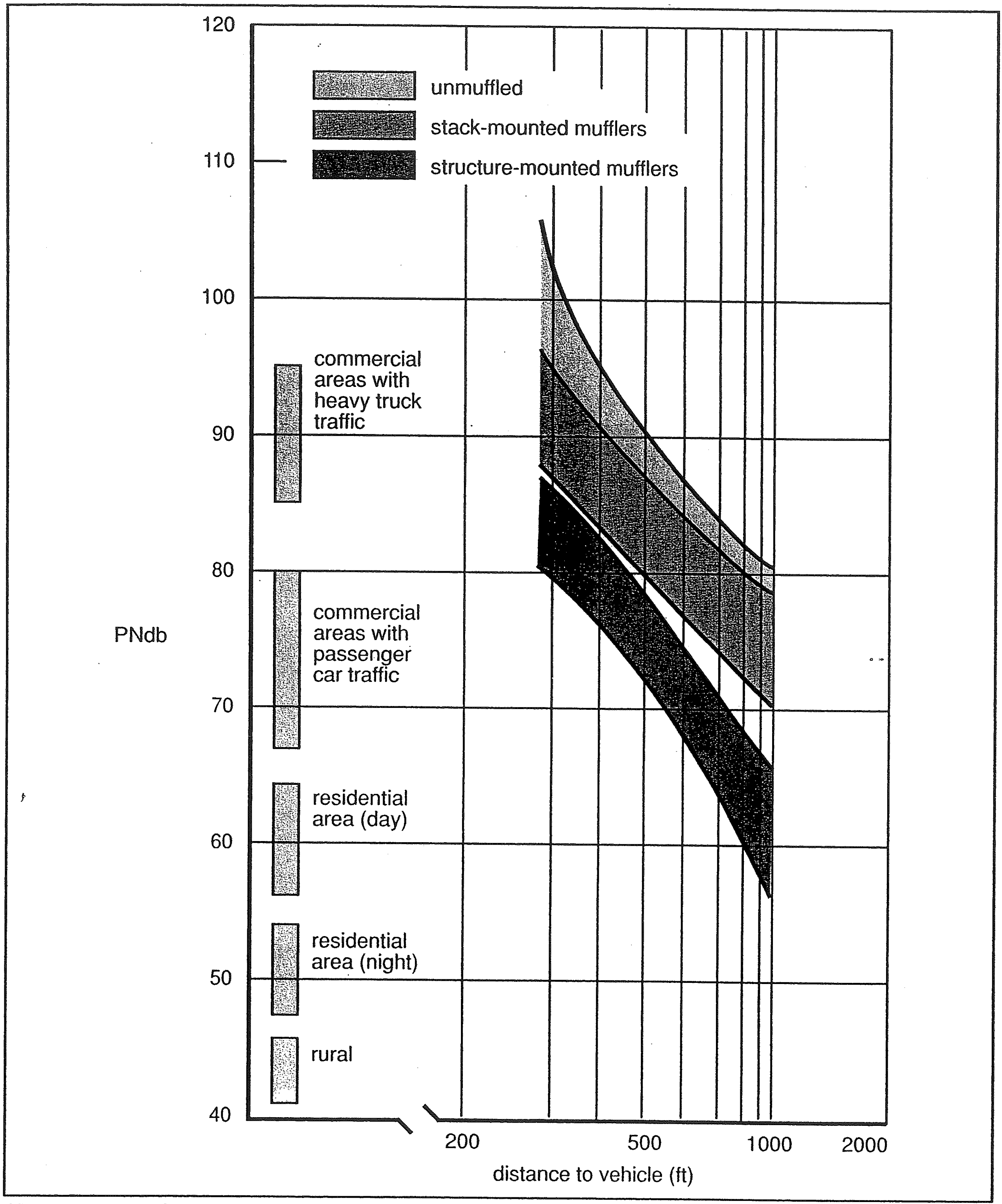

Figure 10. *Exhaust Noise Suppression*

Weather

Although you cannot control the weather, you may be able to adapt your flight schedule to take advantage of meteorological conditions that can help you minimize noise. The two weather factors most useful in this respect are wind and temperature. They are helpful because they affect the propagation of sound, and vary throughout the day in a more or less predictable manner.

Wind has two effects on sound. It carries it in the direction towards which it is blowing, and it makes a background noise of its own that, in high winds, tends to reduce the annoyance of helicopter sound.

In inland areas, surface winds are generally stronger during the daytime, reaching a maximum in midafternoon, and weaker at night. In coastal regions, land and sea breezes (caused by the tendency of land to heat and cool more rapidly than water) give a different diurnal pattern, beginning to blow shortly after sunrise (sea breeze) and sunset (land breeze). You can use these winds to increase the acceptability of your helicopter by flying downwind of densely populated areas and by scheduling the majority of flights after noon near especially noise-sensitive areas.

Temperature likewise has two effects upon sound. One is the tendency of warm air to be more turbulent than cold air, and therefore to disperse sound and decrease its nuisance effect. But the major effect of temperature depends upon the temperature gradient—the change in temperature with altitude. The normal gradient is negative: temperature decreases with altitude.

Because sound travels faster in warmer air, in atmosphere with the normal gradient the lower part of a sound wave tends to outrun the upper part, so that sound propagation effectively curves upward and away from the populace. The negative gradient reaches a maximum in the late morning or just after noon, and is more intense during summer months. This means that it is of some value to schedule flights to and from noise-sensitive areas during the warmer parts of the day.

At certain times, however, there may be an inversion in the atmosphere—a layer of air from a few hundred to a few thousand feet thick in which the temperature increases with altitude. The inversion reverses the normal curvature of sound propagation, turning an abnormally high portion of the sound energy back toward the ground. The most severe inversions usually occur at night and in the early morning. These, then, are times when the sound of the helicopter will have the most adverse effect upon people on the ground.

A third meteorological item that affects the propagation of sound is humidity. But its direct effect—it attenuates high frequency portions of the sound spectrum—is of little importance. As visible moisture, it is important as an indicator: on overcast days of fog, drizzle, or light snow, temperature and wind gradients are generally small, resulting in increased sound propagation. Of all the many combinations of atmospheric conditions, that which does least to reduce the sound of a passing helicopter is a windless, cold, overcast morning. At such times, use the noise-abatement flight techniques.

Although the environment is not, strictly speaking, a meteorological subject, it might be well to mention here that the ground environment has much to do with how offensive the helicopter sound is. The background noise (the sound environment) of residential areas reaches its lowest level between late evening and early morning. In warm weather, people are apt to be relaxing out of doors in the evening and on weekends. It is at these times that people are most conscious and resentful of noise intrusion, and therefore at these times you should be most reluctant to fly noisily near residential areas.

Helicopter Noise Reference

The following figures are offered as reference material for helicopter users to determine the noise level that can be expected, given a specific aircraft type and gross weight.

Figures 12, 13, and 14 are for helicopter noise levels measured in ICAO flight conditions. All values are indicated in Effective Perceived Noise Level (EPNL dB). (See the glossary in the back of this guide for definitions of sound metrics as well as other terminology.)

Figure 11 shows the placement of sound monitoring devices for noise certification procedures. During takeoff, level flyover, and approach, three microphones located at the specified distances and angle from the helicopter monitor the helicopter noise.

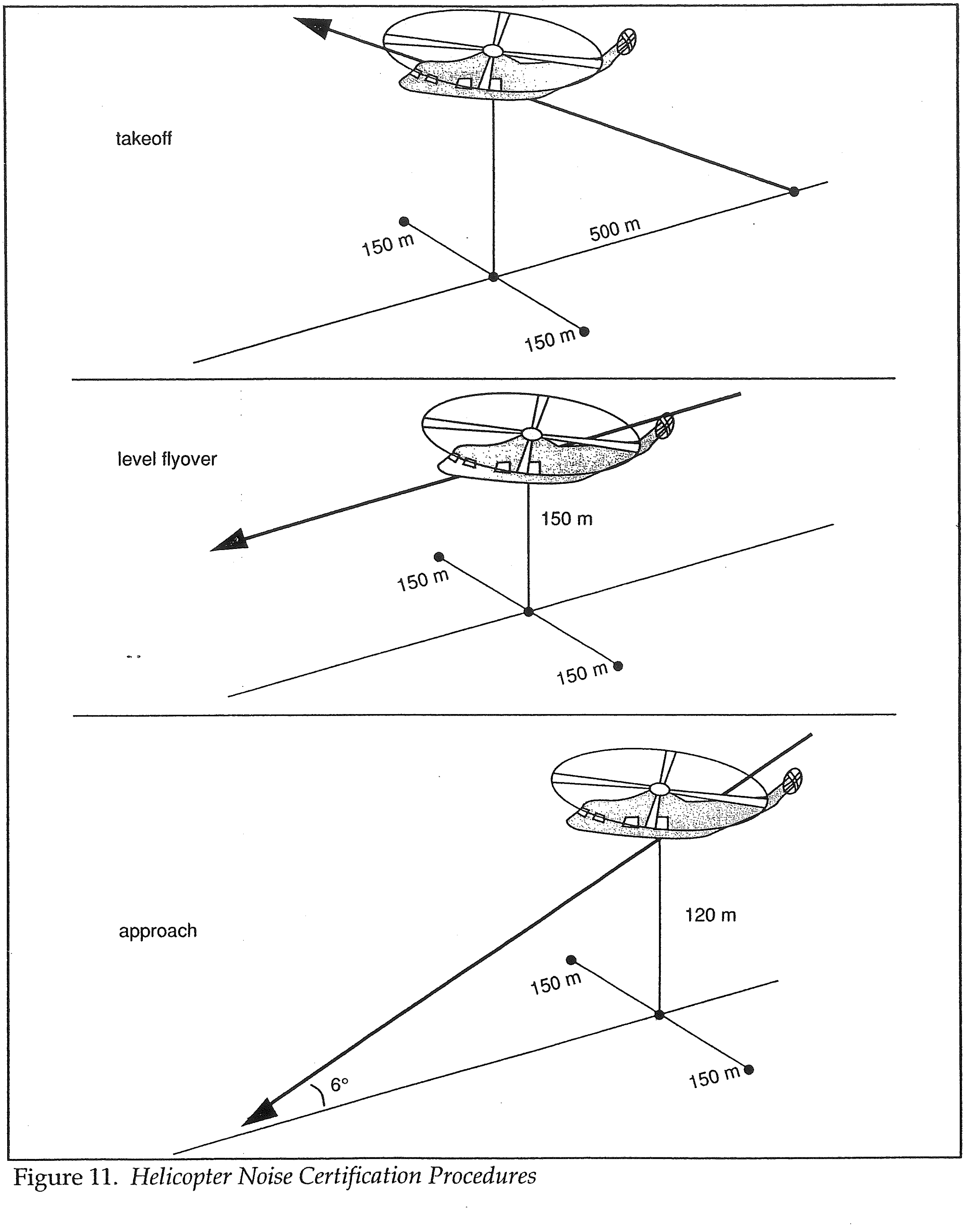

Figure 11. *Helicopter Noise Certification Procedures*

Figure 12 indicates noise levels for takeoff, assuming that the helicopter is stabilized at maximum takeoff power, and at is climbing at the best rate of climb along a path starting from the rotation point located 1640 feet forward of the flight reference point, at a height of 65 feet above the ground, as shown in Figure 11.

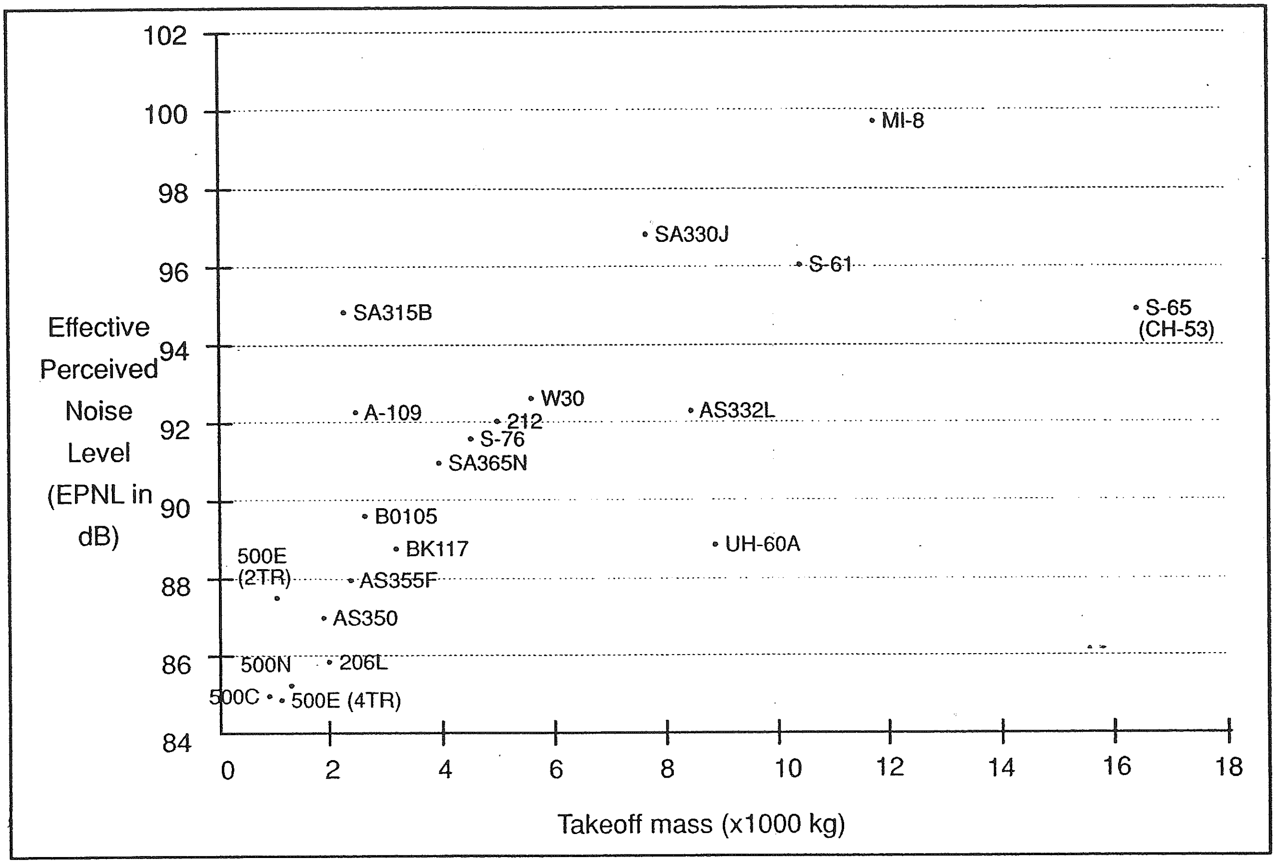

Figure 12. *Takeoff Noise Levels*

Figure 13 indicates noise levels for overflight, assuming that the helicopter is in cruise configuration (90% of VH), and stabilized in level flight above the flight path reference point at a height of 500 feet, as shown in Figure 11.

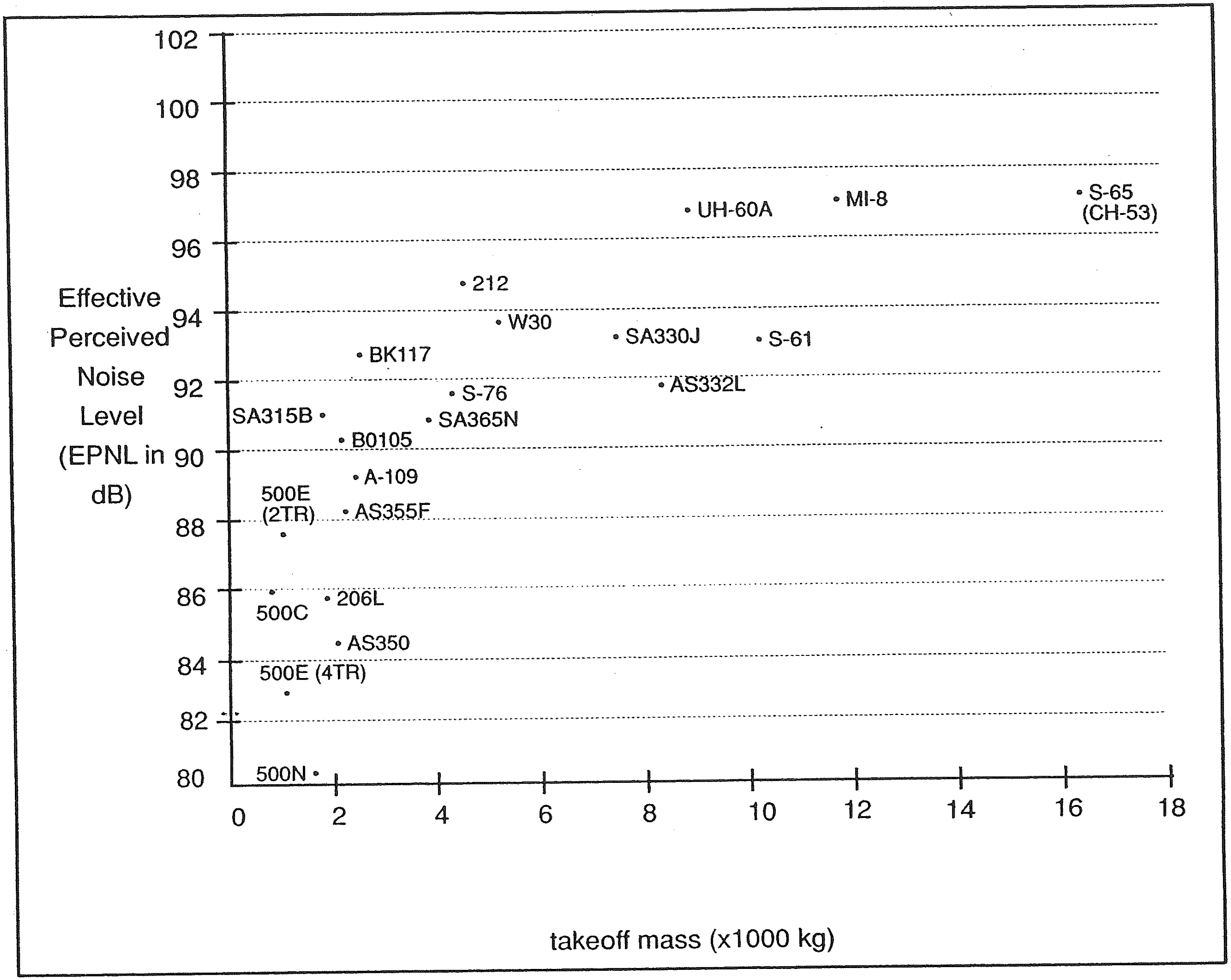

Figure 13. *Level Flyover Noise Levels*

Figure 14 indicates noise levels for landing approach, assuming that the helicopter is stabilized in its landing configuration (90% of VH), and following a 6° approach path, passing above the flight path reference point at a height of 396 feet, as shown in Figure 11.

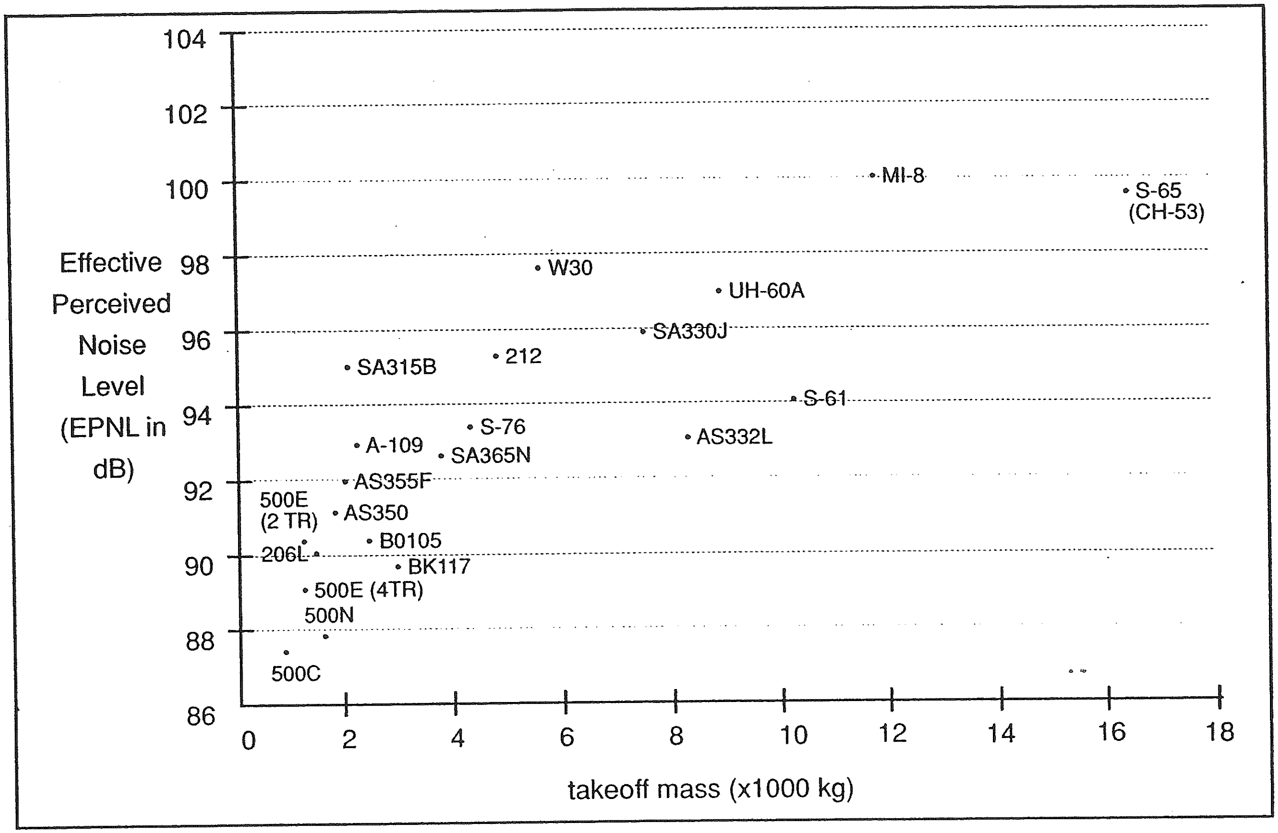

Figure 14. *Approach Noise Levels*

The general relationship between noise level and helicopter weight is shown in Figure 15.

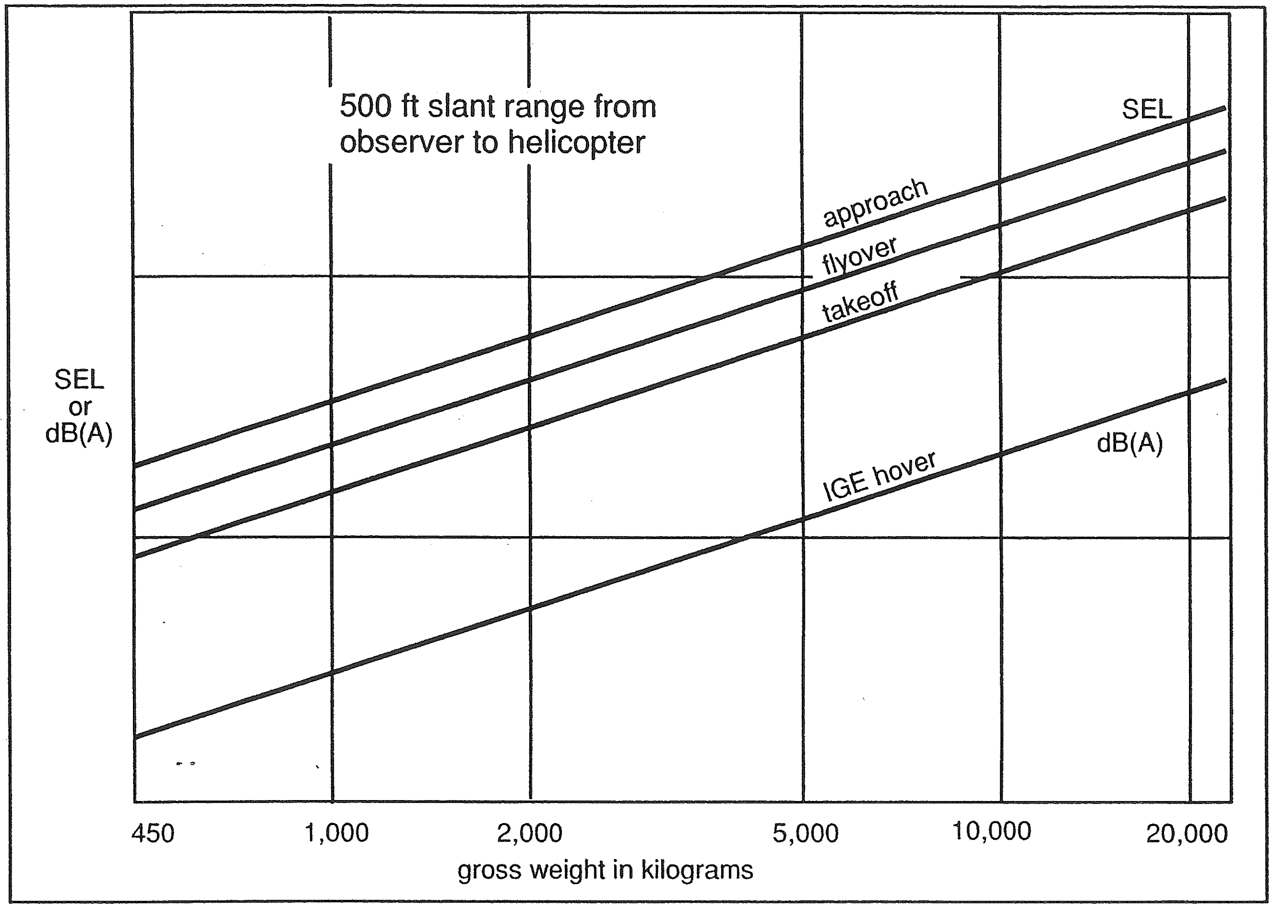

Figure 15. *Relationship Between Noise and Helicopter Weight*

What do these noise levels mean? The following table provides some basis for comparison between the helicopter noise in the figures above, and other, familiar noises.

Table 1. *Illustrative Noises*

dB(A)	**Overall Level**	**Community (Outdoor)**	**Home or Industry (Indoor)**	**Human Judgment of Loudness**
130	uncomfortably loud	military jet aircraft takeoff from aircraft carrier at 50 ft (130)		
120			oxygen torch(121)	120 dB(A) 32 times as loud
110	very loud	turbofan aircraft at takeoff power at 200 ft (118)	riveting machine (110) rock-and-roll band (108-114)	110 dB(A) 16 times as loud
100		jet flyover at 1000 ft (103)		100 dB(A) 8 times as loud
90		power mower (95) motorcycle at 25 ft (90)	newspaper press (97)	90 dB(A) 4 times as loud
80	moderately loud	car wash at 20 ft (89) diesel truck at 40 mph at 50 ft (84) high urban ambient sound (80)	food blender (88) milling machine (85) garbage disposal (80)	80 dB(A) twice as loud
70		passenger car at 65 mph at 25 ft (77)	living room music (76) TV audio, vacuum cleaner (70)	***Reference*** 70 dB(A)
60		air conditioning unit at 100 ft (60)	electric typewriter at 10 ft (64) dishwasher (rinse) at 10 ft (60) conversation (60)	60 dB(A) 1/2 as loud
50	quiet	large transformers at 100 ft (50)		50 dB(A) 1/4 as loud
40		bird calls (44) lower limit of urban ambient sound (40)		40 dB(A) 1/8 as loud
10	just audible	dB(A) scale interrupted		
0	threshold of hearing			

Figure 16 also provides some basis for comparing helicopter noise to other familiar noises.

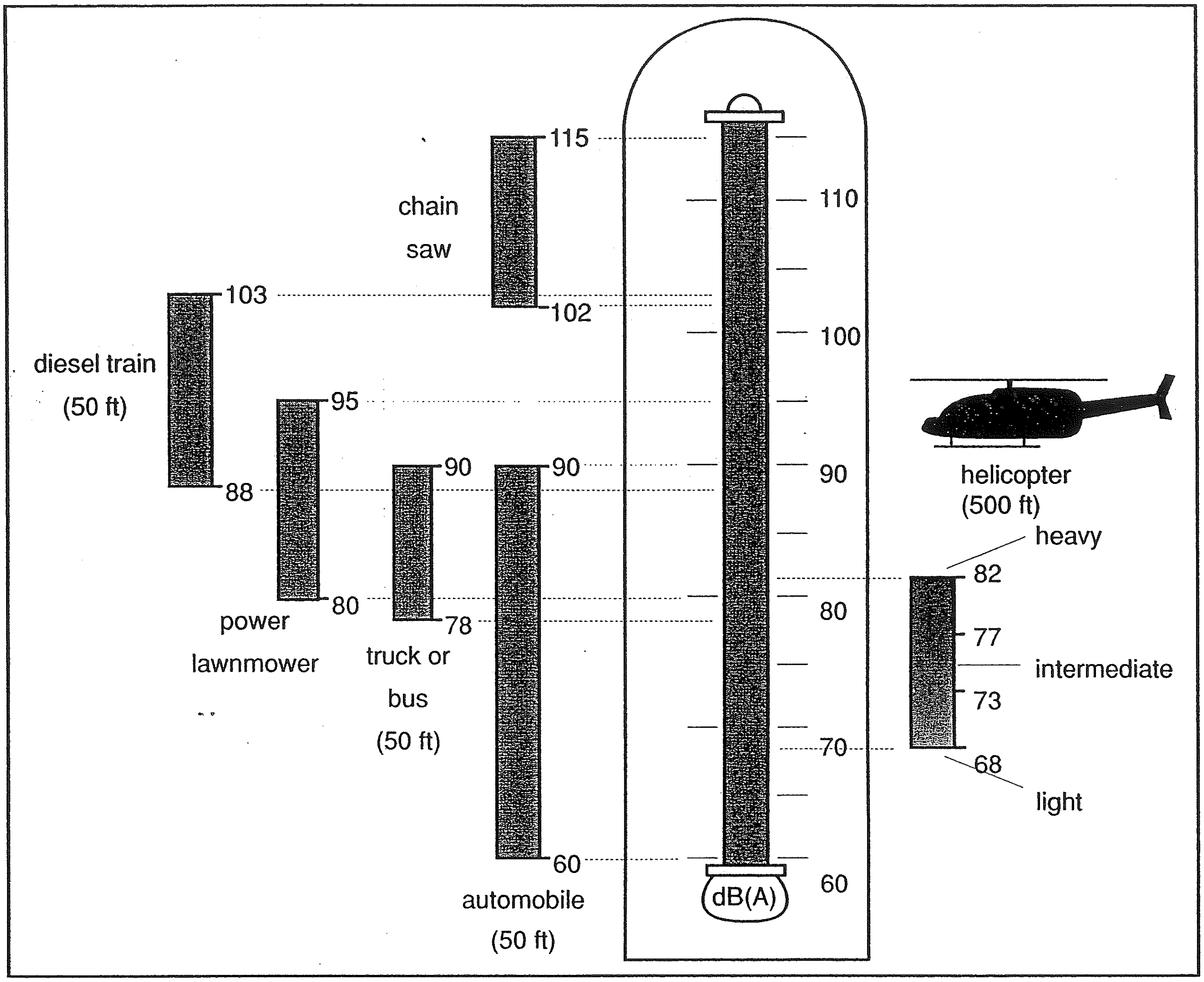

Figure 16. *Comparison of Sounds*

Glossary

The acronyms used in this handbook are defined below.

dB	Decibels, the basic unit for measuring the loudness of sounds.
dB(A)	A-weighted sound level, a sound pressure level that has been weighted to reduce the influence of low and high frequency extremes. Unweighted sound pressure level does not correlate well with human assessment of the loudness of sounds. Therefore, various weightings are added to sound level meters to attenuate low and high frequencies in accordance with accepted equal loudness contours. One of these weightings is designated as the "A" weighting; it correlates well with people's subjective judgments of sound loudness, and is currently used for noise certification of small propeller-driven aircraft. In FAA Advisory Circular 36-3C it is used as the basis for airport access restrictions that discriminate solely on the basis of noise level.
DNL	Day-night sound level, a single-number measure of community noise exposure, introduced to help predict the effects on a population of the average long-term exposure to environmental noise. It is based on the equivalent sound level (Leq), but corrects for night-time noise intrusion: a ten-decibel correction is applied to noises heard between 10 P.M. and 7 A.M. to account for the increased annoyance of noises heard at night. DNL uses the same energy equivalent concept as Leq. The specified time integration period is 24 hours. For assessing long-term exposure, the yearly average DNL is the specified metric in the FAA FAR Part 150 noise compatibility planning process.
EPNL	Effective perceived noise level, a measure of complex aircraft flyover noise, expressed in decibels, that approximates human annoyance responses. It corrects for the duration of the flyover and the presence of audible pure tones and discrete frequencies such as the whine of a jet aircraft. The EPNL is used by the FAA as the noise certification metric for large transport and turbojet airplanes and helicopters.
fpm	Feet per minute, a measure used for the rate of climb or rate of descent of an aircraft.
KIAS	Knots indicated air speed, a measure of the speed of an aircraft.
Ldn	See DNL.
Leq	Equivalent sound level, expressed in decibels—the energy average noise level (usually A-weighted) integrated over some specified time. The purpose of Leq

	is to provide a single-number measure of noise level averaged over some period of time.
mph	Miles per hour, a measure of speed.
PNL	Perceived noise level, a rating of noisiness used in assessing aircraft noise, expressed in decibels. PNL is computed from sound pressure levels measure in octave or one-third octave frequency bands. An increase of ten decibels in PNL is equivalent to doubling the perceived noisiness. Currently, this measure is used by the FAA and foreign governmental agencies in the noise certification process for all turbojet-powered aircraft, and large propeller-driven transports.
R/C	Rate of climb, how fast an aircraft is ascending.
R/D	Rate of descent, how fast an aircraft is descending.
RRPM	rotor revolutions per minute, how fast an aircraft rotor is turning.
SEL	Sound exposure level, a measure, expressed in decibels, of the effect of duration and magnitude for a single event. In typical aircraft noise model calculations, SEL is used in computing aircraft acoustical contribution to the equivalent sound level (Leq) and the day-night sound level (DNL).
VH	Maximum compressor power.
VI	Takeoff decision speed.
Vy	Speed for best rate of climb.

Manufacturers' Contacts

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West Chester, PA 19380
(215) 431-4150

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Mr. Frank Robinson
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Torrance, CA 90505
(213) 539-0508

Rogerson Hiller Corporation
Helicopter Division
Mr. Jim Brown
2140 W. 18th St.
Port Angeles, WA 98362
(206) 452-6891

Schweizer Aircraft Corp.
Mr. Russ Lancaster
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Elmira, NY 14902
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Sikorsky Aricraft
Dr. Charles A. Yoerkie, Jr.
Chief of Acoustics
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(203) 386-7361

Westland Helicopters
E.H. Industries
Dr. John Leverton
1735 Jefferson Davis Hwy, Suite 805
Arlington, VA 22202
(703) 486-8000

Directory of Affiliate Members

The following alphabetical listing of affiliate members contains international, national, and regional organizations whose purposes and interests are similar to those of HAI.

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Moscow—D-362
U.S.S.R.
Director: Yuri Postnikov

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8060 Balboa Blvd.
Van Nuys, CA 91406
(818) 781-5087
Fax: (818) 902-2134
President: Bobby Tucker

Alaska Air Carriers Association (AACA)
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Anchorage, AK 99503
(907) 562-1272
President: Richard Stern

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217 N. Washington St.
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(703) 684-6777
Fax: (703) 739-9279
Executive Director: Morris E. "Rhett" Flater

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Lebanon, VA 24266
(703) 889-4000
President: Bill R. Starnes

Asociacion Espanola de Amigos del Helicoptero
c/o Aeroclub of Madrid
Apartado de Correos 15
Leganes-Madrid 28917 Spain
208-58-01-20
Foreign Relations Representative: Fernando Ortiz de Solorzano

Association of Air Medical Services (AAMS)
(formerly ASHBEAMS)
35 S. Raymond Ave., Suite 205
Pasadena, CA 91105
(818) 793-1232
Fax: (818) 793-1039
Executive Director: Nina Merrill

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c/o Aris Helicopters
1138 Coleman Ave.
San Jose, CA 95110
(408) 998-3266
Fax: (408) 998-4061
Chairman: Stephen R. Sullivan

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Fairoaks Airport
Chobham—Surrey GU24 8HX
England, U.K.
0276-856100
Telex: 940-70214 AVPR G
Fax: 0276-856126
Chairman: D. G. Dollar
Chief Executive: J. P. Durrant

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(ERHC)
c/o Island Helicopter Corporation
North Avenue
Garden City, NY 11530
(516) 228-9355
President: Paul Smith

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Committee (EHOC)
c/o Shell Aircraft Ltd.
Cardinal Point
Heathrow Airport
London TW6 2HF
England, U.K.
081-759-4531
Telex: 919651
Fax: 081-759-4582
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Fax: 02-976-2316
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German Helicopter Association
(Deutscher Hubschrauber Verband eV)
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Fax: 02634-2486
President: Bernhard Liscutin

Groupement Francais de L'Helicoptere
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Honolulu, HI 96815-1605
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Helicopter Association Northwest
Ketchum & Co.
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Bellevue, WA 98004
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Helicopter Association of Florida
P.O. Box 402
Opalocka, FL 33054
(305) 256-2953
President: Benjamin D. Clark

Helicopter Association of Southern Africa (HASA)
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Helicopter Environmental Liaison Office (H.E.L.O.)
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President: Captain E.E. Milam

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Michigan Helicopter Association
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National Broadcast Pilots Association (NBPA)
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Miami, FL 33186
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Fax: (305) 378-4407
President: Maurice Johnson

National Flight Nurses Association
(NFNA)
6900 Grove Rd.
Thorofare, NJ 08086
(609) 384-6725
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President: Leary Cox, R.N.
Executive Director: Lynne Dorcey

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Pilots Association
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Director: John Helm

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(614) 460-3769
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Popular Rotorcraft Association
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Professional Helicopter Pilots Association
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Provo, UT 84603
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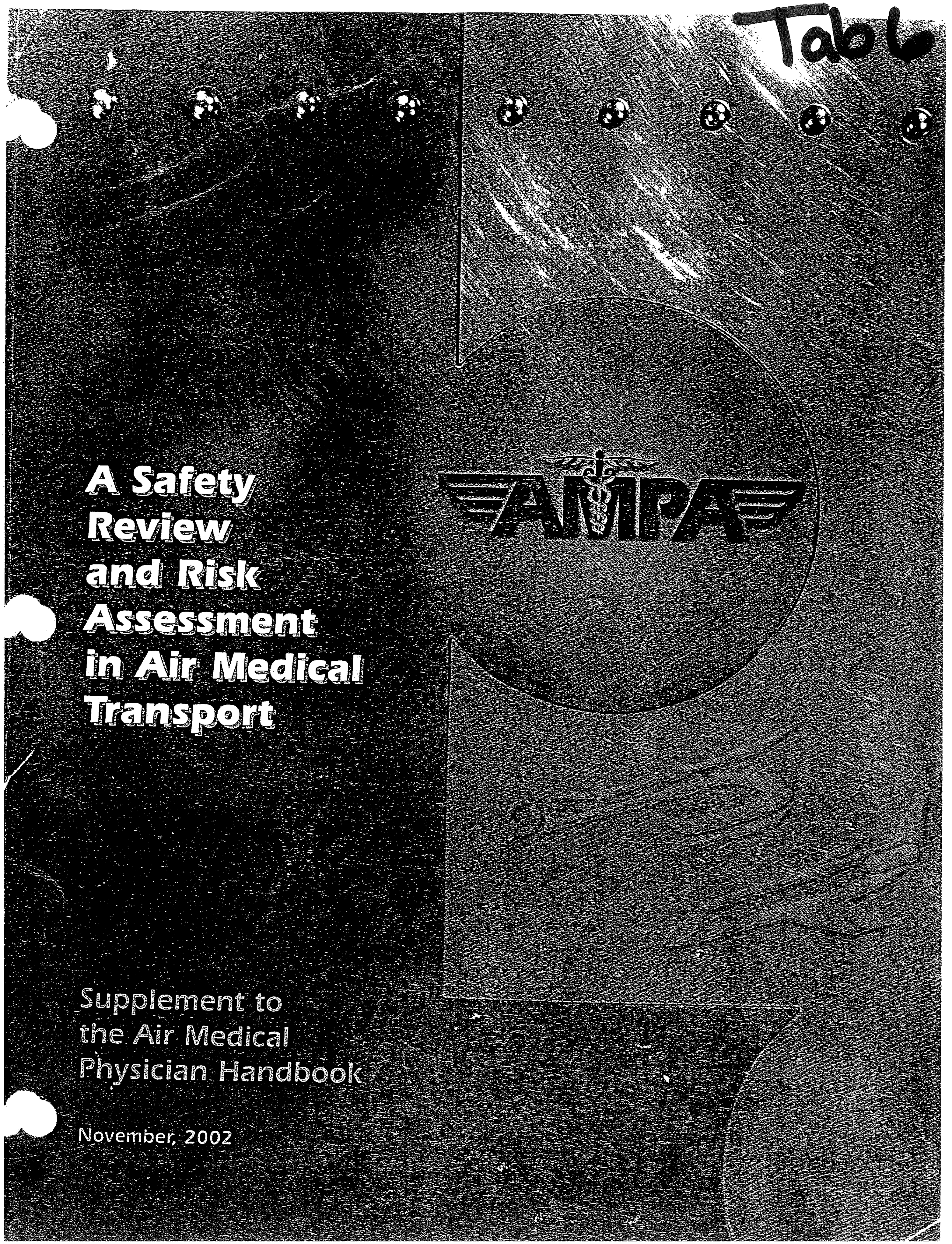
Chairman: Donald G. Andrews

Tab 6



A Safety Review and Risk Assessment in Air Medical Transport

Supplement to the Air Medical Physician Handbook

November, 2002

AMPA

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PHYSICIAN
ASSOCIATION

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November, 2002

To the Air Medical Community,

Safety is a primary concern for all medical transport professionals. Regardless of whether transporting in helicopters, ground ambulances, or fixed-wing aircraft, or if transporting from scenes to hospitals, between hospitals or within a hospital, the movement of patients raises both the risk of medical complications and the risk of transportation accidents and incidents. A great deal of attention has been focused on helicopter incidents and accidents. While improvements in equipment, protocols, training, and operations have occurred, air medical helicopter transport is not as safe as we would like.

In the attached safety report, Dr. Ira Blumen and his team from UCAN provide a fresh perspective on medical helicopter safety statistics and an assessment of risk. They look at the existing data from a variety of viewpoints and have undertaken a unique research project to fill in many of the statistical gaps that previously existed. They compare Helicopter EMS with other aviation data, other routine risks, and provide a basis for future work.

The authors are to be commended for this significant effort. AMPA is proud to make this report available to everyone in the air medical community, and the AMPA Board thanks the many contributors who made this possible.

All of us associated with air medical care should read this report, discuss it with their peers, friends and family, and then read it again. Then they should go to work motivated to improve safety even further. When the second edition of this report is produced, wouldn't it be wonderful to demonstrate lasting improvements in safety, for our community and our patients?

Sincerely,

Kenneth A. Williams, MD, FACEP	Harry E. Sibold, MD, FACEP
President, AMPA	President, AMPA
2000-2002	2002-2004

Air Medical
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2002

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TABLE OF CONTENTS

A Safety Review and Risk Assessment in Air Medical Transport

Ira J. Blumen and the UCAN Safety Committee

Editorials:

Being safe does not eliminate risk—it reduces it. This paper provides valuable information regarding risk that will hope-ly help each and every air medical pro- m and air medical professional better understand their day-to-day risk. More importantly, they will have information that should help guide the coordination, implementation and evolution of a safety and risk management program, thereby reducing the number of accidents and enhancing survivability.

HEMS DATABASE

This investigation began with a comprehensive analysis of various databases to identify individual HEMS accidents and their corresponding fatalities and injuries. Our research model then enabled us to estimate flight hours, patients flown, and other variables for evaluation. Since 1972, HEMS has flown an estimated 3.0 million hours while transporting approximately 2.75 million patients. In 31 years (through September 2002) there have been 162 accidents involving dedicated medical icopters and four accidents involving al-purpose helicopters in the United States. There have been 67 fatal accidents with 183 fatalities, including 144 crewmembers. Since 1998, there have been a total of 50 accidents—nearly 31% of all the accidents we have experienced over three decades.

In the early and mid-1980s, during the HEMS industry's most rapid growth, we experienced an alarming number of accidents. From 1980-1987, there were 54 accidents, averaging 7.7 accidents per year. The late 1980s to mid-1990s showed considerable improvement. From 1987-1997, dedicated HEMS averaged 4.9 accidents each year. From 1998-2001, however, we have seen that average more than double to 10.75 accidents per year. Not since the four-year period of 1983 to 1986 have we seen such a large number of accidents.

The data is not uniformly grim, however. Of the 44 accidents from 1998 to 2001, 15 (34%) resulted in at least one ality. For the 1980s, our accident abase revealed 39% of all accidents resulted in at least one fatal injury, while from 1990-1997, that rate had increased to 47%. Despite the increase in accidents over the past four years, the percentage of fatal accidents has declined by nearly 30% compared to the early 1980s. In addition, the last four years have seen the lowest consecutive 4-year fatality rate in HEMS history since the early 1980s. The percentage of fatal injuries has also decreased in the 1998-2001 accidents and we see a higher percentage of crewmembers and passengers who sustained no injuries. The fact remains, nonetheless, that since 1990, there has been an average of 2.5 fatal accidents annually, taking the lives of 5 to 6 crewmembers each year.

RECURRENT FACTORS IN HEMS ACCIDENTS

This report summarizes several notable publications, investigations and presentations that analyze and identify key factors related to HEMS accidents. Included in these studies were evaluations regarding incident, operational, and human factor variables. The analyses included the severity of injury, when HEMS accidents occur, condition of light, phase of flight, purpose of flight, the cause of HEMS accidents, pilot experience, aircraft damage and occurrence of post-impact fires. Two studies were also included that analyzed the chain-of-events and problems that led to past accidents. These reports propose interventions intended to prevent future accidents.

A disproportionate number of HEMS accidents occurred during night operations. While an estimated 38% of all HEMS flights were at night, 49% of the accidents over 20 years (1978-1998) occurred during night operations. It was also found that more accidents occurred during cruise (36%) than any other phase of flight.

Scene transports also accounted for a disproportionate number of HEMS accidents. Since 1988, the percentage of scene response flights has averaged 31%, while a total of 42% of the accidents during patient-related missions occurred on scene flights. If all missions had equal risk, then 31% of the accidents should have been on scene missions.

Pilot error was attributed as the direct or indirect cause of HEMS accidents nearly three times more often than mechanical failure. The studies we analyzed have associated human factors with 65-76% of the HEMS accidents studied. Of the fatal accidents studied, human error was associated with 84%. Human error was a factor in more than two-thirds of the en-route accidents, more than 80% of the accidents during takeoff, and approximately 90% of the accidents during approach and landing.

In 1988, the NTSB concluded that poor weather poses the greatest single hazard to EMS helicopter operations. Subsequent publications found that in the 1980s, 22% of the accidents were determined to be weather-related. In the early to mid-1990s, 32% were related to weather. Tragically, while the total number of accidents went down, the percentage of weather-related accidents had increased by 10%. Since 1998, however, it appears that this trend has dropped significantly to less than 15%. In addition, 88% of the weather-related HEMS accidents occurred at night. Approximately 75% of all weather-related HEMS accidents resulted in fatalities and nearly two-thirds had no survivors.

In-flight collision with an object (CWO) has occurred with 25 HEMS accidents and there has been a dramatic increase in the number of CWO accidents and incidents over the past few years.

More than 25% of the accidents involving CWOs resulted in fatalities. Sixteen (64%) of these CWO accidents occurred during scene response missions. Once again, if all missions had equal risk, 31% of the CWO accidents should have been on scene missions. Instead that percentage rate has more than doubled. It was also identified that more than 40% of all the approach and landing accidents and 50% of all takeoff accidents were CWOs. Unexpectedly, weather has not been identified as a factor in CWO accidents.

Also unexpectedly, pilot fatigue and total hours of flight time do not appear to be significant factors in HEMS accidents. Analysis of HEMS incidents suggests that an IFR rating and currency may be protective in overcoming situations and avoiding accidents. In addition, communications problems, time pressures, and distractions are frequently identified as contributing risk factors in HEMS accidents and incidents.

The magnitude of injuries and aircraft damage is significant in HEMS accidents. HEMS accidents are more likely to result in fatalities or serious injuries than other helicopter accidents. One study found that main cabin occupants in EMS helicopters have nearly 4.5 times the risk of serious injury (especially back injuries and head injuries) or death in survivable crashes when compared to a comparable population of occupants in the main cabin of non-EMS air taxi helicopters. For front seat occupants, there was no significant difference in injury risk between the two groups. This seemed to support the author's premise that EMS aircraft modifications, which are generally limited to the main cabin, were directly associated with the risk of injury and may contribute to occupant injury and death in otherwise survivable crashes.

Different studies reported the incidence of post-impact fires between 2-15%. Nearly half of the accidents resulted in the destruction of the helicopter. No conclusions, however, can be made regarding single- vs. twin-engine aircraft.

HEMS ACCIDENT AND FATAL ACCIDENT RATES

An important aspect of this study was the determination of HEMS accident and fatal accident rates for the defined study period (1980-2001). Calculations are based upon estimated exposure data, which has been determined through several industry-wide surveys, various calculations and several assumptions, which are stated.

An extensive review of the air medical literature was conducted to determine what data was available. Total flight hours and total patients transported were unavailable for more than 50% of the years reviewed. For various years, published data included: average flight hours per program, total patients transported, average patients transported per program, loaded miles, and average flight hours per patient transport. Unfortunately, there was no data regarding the number of HEMS programs or dedicated helicopters n operation since 1992.

Considering the available vs. unavailable information, it was concluded that if the number of programs and helicopters in operation could be determined, then the total flight hours and patients transported could be estimated for the year. Furthermore, an assumption was made that the growth in the HEMS industry has been fairly constant since 1992. It would then be possible to estimate the number of programs and helicopters for the years lacking data.

To determine a fairly accurate number of dedicated HEMS programs and helicopters, several steps were performed. First, a state-by-state survey was posted on the *Flightweb* listserve. The resulting information was supplemented by the AAMS Membership Directory and the "Directory of Air Medical Programs" published in *AirMed*. To further supplement these results, information was obtained from the helicopter manufacturers and a survey of five of the largest HEMS operators was conducted.

It was also determined that our research model should include *total* flight hours in this evaluation. In HEMS, a considerable number of accidents occurred on non-patient missions—including public relations (PR) flights, refueling, maintenance, training, and so on. Personal correspondence with several HEMS programs and operators suggests that non-patient flight time may range from 5 to 15%. PR flights made up approximately half of this for many programs. In an effort to more accurately determine the average number of total flight hours per program, additional information was obtained from the surveyed HEMS operators.

The survey results identified 231 dedicated HEMS programs, operating a total of 377 helicopters (excluding back-up aircraft). Subsequent discussion with several industry leaders and evaluation of information from the aircraft manufacturers suggests that, if anything, these numbers may be slightly underestimated. The helicopter manufacturers estimated that there were 462 medical helicopters (dedicated and backup) in the United States, not including dual-purpose helicopters. With an average of one backup for every 7.1 dedicated helicopters in the combined operators fleets, there are an estimated 53 backup aircraft yielding a total of 430 helicopters. This represents a variation of approximately 7% fewer aircraft compared to the number of helicopters from the manufacturers' survey. This may also indicate a slight discrepancy in the number of HEMS programs resulting from th Internet survey. In using the lower state-by-state survey results of 377 dedicated helicopters and 231 programs for our calculations, it is realized that the proposed exposure data (flight hours and number of patients transported) may be underestimated. As a result, the calculated accident and fatality rates could be overstated by an estimated 7-10%. This difference, however, does not impact the overall trends identified in HEMS accidents nor the comparison with other aviation operations.

The calculated results show a dramatic decrease in the HEMS accident rate since the mid-'80s. As the raw data would predict, the accident rate since 1998 has steadily increased. However, despite this increase, the rate remains roughly one-third of what was experienced in the early to mid-1980s due to the overall increase in flight hours.

Looking at an average accident rate for 1992-2001, (3.78 accidents per 100,000 flight hours), the average HEMS progra flying 911 hours per year, would have one accident over 29.1 years of flight time. If a program flies less, the number of years would presumably increase, and if a program flies more, the time frame would decrease. Another way to propose the likelihood of an accident would be to compare the number of accidents to the number of programs (or helicopters). Again, using the most recent ten years, there has been an average of 7 accidents each year. With 231 dedicated HEMS programs, and assuming all things being equal, we would find a similar prediction of one accident per program every 33 years. If you base this comparison on the number of dedicated helicopters estimated for 2001 (400) rather than programs, the margin now goes up to nearly 57.1 years. Looking at the average number of HEMS accidents (9) for the past five years, we would expect one accident per helicopter every 44.4 years.

The second comparison looks at the fatal accident rate per 100,000 flight hours. Here too, a dramatic improvement is identified since the early and mid-1980s. Our current rate, despite having gone up slightly over the past few years, is approximately 75% less than our worst years. Once again if we take an erage flight program and an average l accident rate for the past ten years (1.38 fatal accidents per 100,000 flight hours), we would predict one fatal accident while flying for over 79.3 years. When we focus on the average fatal accident rate for 1997-2001 (1.69) this figure drops to 64.8 years.

The final normalized comparison evaluates the accident rate per 100,000 patients transported.

With a 10-year (1992-2001) average accident rate of 3.89 accidents per 100,000 patients transported and the typical HEMS program flying 882 patients in a year, a program would have one accident while transporting an estimated 25,700 patients over 29.2 years. Calculations for 1998-2001 (4.79 accidents per 100,000 patient transports) resulted in an estimate of one accident while transporting nearly 21,000 patients over a 23.74 year period.

A final annual comparison of HEMS accidents considers the percentage of HEMS programs and helicopters that e sustained an accident. These calculations do not take into account the possibility that an individual program may have suffered more than one accident—which has occurred. Overall, the 22-year average annual percentage calculates to 5.8% of the programs having had accidents between 1980 through 2001. If one considers only the past five years, an average of 4.1% of the programs have had an accident each year. In 1982, an estimated 16.3% of the HEMS programs (8 accidents, 49 programs) were involved in accidents. The safest year was in 1996, when an estimated 0.5 % of the programs had an accident (1 accident, 207 programs).

Calculating the percentage of helicopters that were involved in HEMS accidents each year finds a high of 12.9% of the HEMS aircraft in 1982 (8 accidents, 62 helicopters). In 1996, there was 1 HEMS accident during a year when an estimated 309 dedicated medical helicopters were in operation, for a total of 3%. The average percentage over 21 rs calculates to 4.4% of the HEMS fleet. Over the past 5 years, this percentage has averaged 2.5% for each year.

HEMS COMPARED TO OTHER AVIATION OPERATIONS

Raw data and normalized statistics are available from the FAA/NTSB for the different types of aviation operations. With the estimated accident and fatality rates per 100,000 flight hours for HEMS, it is now possible to compare various types of aviation in a more meaningful way.

The accident rate for HEMS was dramatically higher than for all other aviation operations during the early and mid-1980s. Beginning in 1987, we see a sharp decline in the HEMS accident rate, which has remained consistently below the accident rates for both general aviation and all helicopter aviation. In addition, from 1987 through 1997, the HEMS accident rate was lower than the overall accident rate for all Part 135 non-scheduled flights 6 of the 10 years. Since 1998, however, the HEMS accident rate has surpassed that of the non-scheduled Part 135 operations each year

Comparing the average accident rates for the past 20 years (1982–1999), 10 years, and 5 years for the five types of aviation operations, helicopters, and HEMS yield some interesting findings. Even with the high accident rates of the 1980s, the 20-year average for HEMS is below all helicopter operations and general aviation. For the 10-year average, the HEMS accident rate is less than 50% the rate of helicopters and general aviation. For the past 5 years, the average accident rate for HEMS has gone up, but remains significantly lower than all helicopter operations and general aviation.

Initially, the fatality rate for air medical helicopters was equal to or dramatically higher than all other aviation operations. In 1990, however, there were no fatal HEMS accidents. From 1992 to 1997, HEMS was consistently below both general aviation and all helicopter operations in fatal accidents. Since 1998, the HEMS fatality rate has been consistently higher. Looking at the average fatal accident rate for the past 20 years, 10 years, and 5 years for the various aviation operations, HEMS has a higher fatal accident rate than all other aviation during the 20-year period. However, over the past 10 years HEMS has averaged a lower fatality rate than helicopters and general aviation (Part 91). For the past 5 years, however, the average HEMS fatality rate once again exceeded all other aviation operations.

A COMPARISON OF RISK

In order to assess and compare risk, the relevant figure needed must be in the form of a ratio, fraction, or percentage. To arrive at these figures normalization of the data had to occur and we needed to know two primary numbers. The numerator of the fraction tells us how many individuals doing a particular activity were either injured or killed over a given period of time. The denominator represents how many people were engaged in that activity—the population at risk. By reducing all risks into ratios by utilizing this format we can begin to compare different types of activities and the relative risks.

If one were to try to compare air medical transport to other occupations or "routine" risks to determine either the odds of death in one year or the fatality rate per 100,000 (the most common comparison) we would need to know two things. The first is the number of HEMS crew fatalities per year. The second would be the number of people engaged in HEMS transport (i.e., the number of HEMS pilots and medical crewmembers) for each year. The number of fatalities is known, but the number of crewmembers in HEMS has never been tracked.

For the purpose of this study, the average number of crewmembers per helicopter is estimated to be 22 persons (4 pilots, 6-8 nurses as the primary caregivers, and 10-12 second medical crewmembers). In 2001 there were an estimated 400 dedicated medical helicopters, producing an estimated population at risk of approximately 8,792. Having estimated the number of helicopters for each year in this study, the number of crewmembers can be approximated for each year.

It is important to realize that in estimating exposure in this method, it does so for the *average* crewmember and the *average* flight program. When the raw data is normalized, it does not take into account the *amount* of exposure for an individual during the year. For this portion of the study, calculations are based on the average program, which in 2001 transported approximately 882 patients, flying an estimated 957 hours over the course of the full year, and all crewmembers (pilots and medical crewmembers) flying an equal amount of time.

Fatality and Death Rates

Fatality statistics for HEMS personnel are presented in several different formats. In each case, the number of crew fatalities was determined for each year. To be consistent with statistics from the National Safety Council (NSC), the data was normalized to produce a death rate per 100,000 population at risk for each given year. Over the 21 years reviewed for this portion of the study (1981-2001), the HEMS population has grown from approximately 858 to 8,792. While this growth seems impressive, this is still a very small sampling to translate to a ratio per 100,000. With such a small population base, each fatality has a significant impact on the fatality rate. In this design, the range for the HEMS crewmembers fatality rate is from 0 to 699 per 100,000. With such a wide range, a 22-year average was calculated and used in the various comparisons. The average annual death rate over the 22 years is 196 per 100,000 crewmembers.

Another relationship used to compare the annual number of HEMS crew fatalities is in terms of "odds." For example, in 2001there were only two crew deaths out of an estimated crew population of 8,792. Looking solely at the numbers, the odds to an individual crewmember suffering a fatal accident that year would be considered to be 1 in 4,396. Contrasting this with what could be considered our riskiest year (1980), there were 6 crew fatalities out of an estimated 858 crewmembers industry-wide. This would correspond to fatality odds of 1 in 143. Excluding 1990 when there were no fatalities, the average odds per year over the 22-year period are 1 in 1,158.

To further illustrate the risk related to HEMS transport, we can compare and contrast the above numbers with other activities, other types of accidents, and other causes of death. Taking into consideration the wide range of fatality rates and odds that we have estimated for each year in HEMS, the calculated averages are used in subsequent comparisons.

In 1998, the death rate per 100,000 for all accidental deaths was 36.2. Motor vehicle accidents were the highest in this category with 16.1 deaths per 100,000 individuals. When one considers the average annual death rate (192) for HEMS crewmembers over the 22 years reviewed, HEMS is surpassed only by heart disease (268.2 deaths per 100,000) and cancer (200.4 deaths per 100,000) when the data is normalized. The average one–year odds of 1 in 1,158 for HEMS crewmembers is also higher than the one-year odds for all deaths due to injury (1 in 1,796) and all accidental deaths (1 in 2,762).

A final comparison looks at the estimated exposure that will produce a 1 in 1,000 risk of death.

In the 22-year HEMS study period an estimated 3,002,176 total hours have been flown. Adding together the estimated number of crewmembers each year yields a total of 105,922. This corresponds to an average exposure of 28.3 hours of flight time producing the estimated odds of 1 in 1,158. Adjusting the ratio to 1 in 1,000, we get an average exposure of 32.9 hours.

HEMS: The Risk to the Patient

There is some level of risk related to all aspects of healthcare. The results of two comprehensive studies have suggested that between 44,000 and 98,000 Americans die in hospitals each year as a result of medical errors. Normalizing these numbers produces a death rate between 131 and 292 per 100,000 patients due to medical errors. The NSC, however, provides statistics on "complications of surgery/medical care" that is based upon the reported number of deaths compared to the entire U.S. population. Their finding of 1.2 deaths per 100,000 individuals is dramatically different.

While air medical *transport* is not a medical *treatment* and aviation accidents would not be considered a medical error, some could argue that these accidents represent an adverse event in the healthcare environment. In our 22-year study, we estimate a total of 2,745,207 patients have been flown by HEMS. Over this same time period, 21 patients have lost their lives in HEMS accidents. This corresponds to a death rate of 0.76 per 100,000 patients flown. Based upon these figures, it would appear that there is a far greater risk to the patient of dying from an adverse event while hospitalized than from an accident aboard a medical helicopter.

Occupational Risks: Deaths and Injuries in the Workplace

The NSC reports an average death rate across all industries at 3.8 per 100,000 workers, with mining (21.2) and agriculture (22.5) having the highest rates. With a death rate of 192 per 100,000, the HEMS death rate is approximately nine times greater than the riskiest industries. However, it must be pointed out that this comparison is greatly distorted when you consider the small HEMS "population." Even in 2001, with our largest estimated number of crewmembers, 2 fatalities resulted in a death rate of 23 per 100,000.

RISK MANAGEMENT IN HEMS

A HEMS accident is not caused by a single event, but by a chain of events. In most accidents, numerous risk factors can be identified. Acting on any of these risks and breaking the chain at any point may prevent an accident from occurring. Safety of flight requires the right attitude and active participation. Every pilot, mechanic, medical crewmember, communication specialist, and administrator must be fully knowledgeable of their role and responsibilities. Each must be committed to a safe operation and to ongoing risk management. Nothing takes the place of comprehensive training, proficiency, and sound judgment.

An important training component should be Air Medical Resource Management. The goal of AMRM is to improve crew communications and interactions by addressing teamwork, communication skills, decision making, workload management, situational awareness, preparation and planning, cockpit distractions, and stress management.

The risks in HEMS should not be underestimated. The cumulative effects multiple risk factors must be considered when making decisions on each and every transport. Risk management is a major component of the decision-making process. It relies on situational awareness, problem recognition, and exercising good judgment to reduce risks associated with each flight.

Accident prevention must be the objective. But there will be "a next accident." The air medical community and each program must be certain that the proper aircraft, systems, training, and equipment are in place to enhance the survivability of an accident. A study that evaluated the use of helmets in survivable military crashes found that main cabin occupants with no helmet were at 5 times the risk for a serious head injury and 7.5 times the risk for a fatal head injury than their helmeted counterparts. Another series of U.S. Army studies found that shoulder harnesses were an important factor in reducing the incidence and severity of serious back injuries. Yet, not every crewmember wears a helmet, not every aircraft is equipped with shoulder harnesses and not every person buckles their seat belt prior to takeoff.

CONCLUSION

Throughout all types of industry, there is generally a 20/80 ratio when it comes to accidents: 20% of all accidents are caused by machine-related problems and 80% of the accidents are caused by human error. This seems to be accurate for HEMS as well. The NTSB commonly identifies "pilot error" as the probable cause in the majority of HEMS accidents. But is it truly *pilot* error? Or have we all failed in some way?

There is no logical reason for the increase in the number of accidents over the past several years. We have regulations, we have safety committees, we have standards, we have safety summits, we have AMRM, we have surveys and we have reports. We have better aircraft, we have newer technology and we have accreditation. And we have 30 years of experience. What we also ***still*** have are unnecessary pressures, unnecessary risks, unnecessary distractions, poor communications, complacency—and the same old human errors. What we do ***not*** have is an excuse!

This report provides a comprehensive review of past studies and offers considerable new information regarding accident rates and risks related to HEMS. This report does not provide the solution to a safer industry. Only you can do that—at your program, on your next flight, on every flight. By providing new information and increasing awareness, we hope to decrease future accidents, and to better educate flight program personnel of the potential risks at hand each and every time the phone rings and the aircraft lifts off.

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A SAFETY REVIEW AND RISK ASSESSMENT IN AIR MEDICAL TRANSPORT

INTRODUCTION

For nearly thirty years, safety has been a focus of committees, articles, lectures, position statements, standards and recommendations within the helicopter EMS (HEMS) industry. Despite the safety programs and safety initiatives industry-wide and program-specific, helicopter EMS accidents continue to occur. HEMS has been credited with saving the lives of tens of thousands of critically ill or injured persons. Tragically, however, there have also been over 150 lives lost due to helicopter accidents in the pursuit of these life-saving missions.

Does the fact that HEMS accidents occur every year suggest that air medical transport is unsafe? Are HEMS crewmembers at a significantly higher risk for injury or death? This report will try to answer these questions by reviewing accident data and trends, identifying potential causes of helicopter accidents and incidents, and reviewing accident and injury rates.

Nothing we do is completely safe. In a 1972 U.S. Supreme Court decision, the court concluded that "safe is not the equivalent of risk free." There are risks, often potentially serious ones, associated with every occupation, every mile traveled, every food eaten, every hobby, every investment – basically with every action we take. Clearly, some actions are riskier than others and the only way to eliminate risk from any activity would be to avoid participating in it completely.

As health care providers, we are constantly faced with risk. We make patient care decisions based upon the related risks and benefits of any given treatment or transfer. The Emergency Medical Treatment and Active Labor Act (EMTALA) requires that we "inform the individual (or a person acting on the individual's behalf) of the risks and benefits..." and document that the benefits of transfer outweigh the increased risks to the individual.

In air medical transport safety must be the top priority. We must also consider the risk related to air medical transport—not just to satisfy EMTALA—but to assure that procedures are in place to avoid *unnecessary* risk and that proactive steps are taken to control risk.

This report reviews and summarizes some of the most important publications, presentations, and studies that address various aspects of helicopter EMS accidents. In addition, we describe an extensive research project and our results that enable us to better understand the risks related to air medical transport.

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REVIEWING THE DATA

There are many ways to review the [illegible]ty of air medical transport and to [illegible]ss the relative risk to its crewmembers. One can look at the safety record and practices of an individual program or look at the industry as a whole. Section 1 of this report looks at the accident and incident data that is specific to the HEMS industry. Another approach is to compare the accident data with that of other forms of air travel and other modes of transportation. This approach is taken in Section 2. Finally, Section 3 compares the identified risks for HEMS to other occupations, high-risk activities, and various routine daily activities.

When looking at accident data, it is common to talk about raw numbers (number of accidents), percentages, or accident rates. But what does that really mean? How can we look at the data, compare statistics, and arrive at conclusions? The Office of System Safety within the Federal Aviation Administration (FAA) has stated that research has shown the importance of comparing like groups when comparing accident data or [illegible]ty performance. For example, a com[illegible]ison of one year's HEMS accident statistics with another year's HEMS accident statistics is more likely to be accurate and meaningful than a comparison of general aviation accident data to HEMS data. It may also be helpful at times to look at different categories of aviation to try to draw comparisons and conclusions.

There is no consensus among researchers and participants in the aviation industry as to what constitutes "safety data." In addition, when interpreting comparisons, equivalent types of data are more likely to be accurate than comparisons of different types of data. Therefore, we must first level the playing field in terms of exposure to risk. It is essential that accident and incident data be "normalized." Raw data on accidents and incidents must be converted to accident or incident rates before it can be used for drawing conclusions about safety over time, or to compare different types of aviation, airplanes, pilots, types of operations, and so on.

Comparisons based strictly upon the number of events that occur may not tell the real story. To be meaningful, comparisons must be based upon equal exposure to risk. The longer we are exposed to a particular risk, or the more times we undertake an activity involving risk, the greater the overall risk. However, this alone does not determine total risk. Reduction factors such as experience, proficiency, equipment, and flight conditions can have a significant positive impact on safety.

The FAA and other organizations track aviation data in a number of different ways. The most common method is with respect to flight hours and departures. The data is then normalized in terms of accidents (or fatalities) per 100,000 flight hours or accidents (or fatalities) per 100,000 departures (i.e., takeoffs). In most aviation, unlike HEMS, takeoff and landings are the higher risk periods. Therefore, short and multiple stop flights are riskier mile-for-mile than long nonstop flights. Airlines generally prefer to focus on accident rates per mile, which makes air travel seem very safe.

The FAA estimates the total flight hours for general aviation based on a survey of a sample of aircraft owners and operators. Scheduled air carriers, on the other hand, must report flight hours, departures, and passengers carried, so their accident statistics may be compared using either departures or flight hours. In the early 1980s when data was kept for HEMS, it was tracked in terms of flight hours and patients transported (which is different than departures). Unfortunately, the air medical transport industry has been unable to develop a consistent method to track its own data – a problem that has recently drawn a great deal of attention. However, numerous calculations are outlined later in this report to make some appropriate comparisons with HEMS.

In much the same way that the FAA normalizes its data, similar strategies must be used to compare the risk of injury or death. To assess the magnitude of risk, we must again normalize the data in some fashion. In this case, the relevant figure is in terms of a ratio, fraction, or percentage. By reducing all risks to a common format, we can begin to compare different types of activities and the relative risks. The larger the percentage, the riskier the activity.

SECTION 1: AIR MEDICAL ACCIDENTS AND INCIDENTS

This section presents an overview of HEMS accidents and reviews several notable investigations. The first, from a series of articles written by Rick Frazer and published in *AirMed*, presents a 20-year review of air medical accidents and specific types of accidents. Second is a 1988 report of 59 HEMS accidents (1978-1986) by the National Transportation Safety Board (NTSB). The next study by Patrick Veillette is from the Flight Safety Foundation (April [illegible]1) and reviews 87 accidents from [illegible]87 through 2000. A 1994 study by the NASA-Ames Research Center is then summarized which evaluates air medical incidents, rather than accidents. The final report in this section is the "Air Medical Accident Analysis" which analyzed past accidents and identified interventions to prevent future accidents. This section concludes with a review of the 1998-2001 HEMS accidents and finally with a comparison of HEMS accident rates, which are based upon available data, research, several necessary assumptions, and various calculations.

BACKGROUND

Air medical transport began in the military, which laid the groundwork for the air transport of critically ill and injured patients. The first civilian air medical operations were established in the late 1960s in the form of dual-purpose programs, which combined the function of public safety agencies with EMS missions. In 1972, the first fatal EMS-related accident occurred within one of these dual-purpose programs. That same year, St. Anthony's Hospital in Denver established the first dedicated hospital-based HEMS program.

In the 1970s and '80s, various publications and organizations tracked the growth of the dedicated helicopter EMS industry. The number of dedicated programs grew slowly in the '70s, but gathered significant momentum in the early 1980s. In 1981 there were 45 programs and by 1986 the industry had almost ipled to 129 programs. Unfortunately, this was accompanied by an increase in the number of air medical accidents.

In the late 1980s new trends were seen. More programs added a second helicopter to their operation, while other programs closed down. In many areas competition was fierce. By 1990 there were 174 programs operating 231 helicopters.

In the '90s, air medical programs and industry-wide statistics became increasingly difficult to track. While new programs started and helicopters were added to many established programs, others merged operations and still more closed. Fixed-wing (airplane) air medical transport continued to grow and became an integrated component of the industry. During this time, the industry did not maintain an accurate census. In addition, industry-wide data was not kept as to the total number of patients transported or the total number of hours flown. The importance of this data will become evident later in this report.

AN OVERVIEW OF HEMS ACCIDENTS: 1972 TO 2002

This research study, developed by members of the UCAN Safety Committee, began with a comprehensive review of numerous databases to identify HEMS accidents and their corresponding fatalities and injuries. Since the introduction of civilian HEMS in 1972, the United States has experienced 162 accidents involving dedicated medical helicopters and four additional accidents involving dual-purpose aircraft. Of these accidents, 67 have resulted in at least one fatality. Figure 1–1 shows the total number of HEMS accidents and fatal accidents (an accident where at least one occupant died) broken down for each year since 1980. As the lines in gray show, until the last few years, the highest number of accidents occurred in the mid-1980s—the same time that the industry experienced its most rapid growth. The arly and mid-1990s showed an improvement, but unfortunately, 1998–2001 showed a steady increase in accidents. Fortunately, the number of fatal accidents did not rise at the same rate.

The NTSB defines an aircraft accident as "an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage." An incident means "an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations." The NTSB also classifies the severity of various injuries that may occur from an accident as fatal ("any injury which results in death within 30 days of the accident"), serious, minor, or none.

When reviewing any accident database or report, it is essential to know the inclusion and exclusion criteria for the data that is used. There are many agencies, organizations, and individuals who maintain and track data regarding HEMS accidents and incidents. There is not always agreement on what should be included in a report or study. Some studies look at only patient missions. Others will look at non-patient missions as well. Some reports include fixed-wing (FW) as well as rotor-wing (RW) and some databases include incidents as well as accidents. An accident database may include only dedicated air medical services, while others might include dual-purpose (e.g., police, fire) aircraft. There is no right or wrong way, but it is essential to know what is included in each statistical review.

The accidents listed in Figure 1–1 are the end product of a detailed review of various personal databases, publications, and Internet websites. In numerous cases, available information was insufficient to determine inclusion vs. exclusion into our own database. To clarify the accident information, direct communication by telephone or email was also employed. Included in this table are dedicated medical helicopter accidents that occurred on either patient or non-patient missions. Also included are known accidents involving dual-purpose helicopters (a total of four accidents and nine fatalities) that crashed during medical missions. Fixed-wing air medical accidents, military accidents and international accidents have not been included in our database or statistical analysis.

Our review found 162 HEMS accidents in which we identified a total of 183 fatal injuries. Accidents have taken the lives of pilots, nurses, physicians, paramedics, respiratory therapists, patients, police officers, fire fighters, and observers. There were also 60 individuals who suffered serious injuries and 73 with minor injuries. A total of 195 people were not injured. Figure 1–2 shows a breakdown for injuries and fatalities for each year in our study. We have also included year-to-date information for 2002.

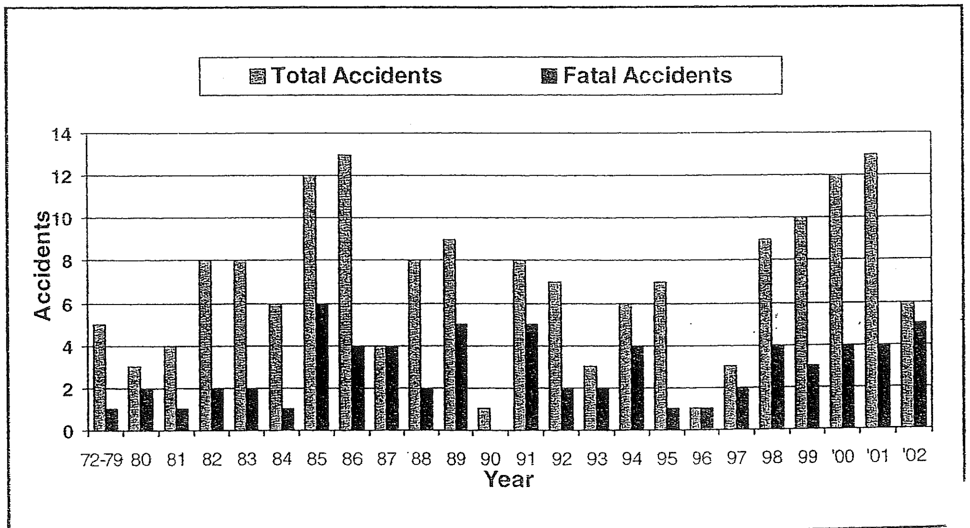
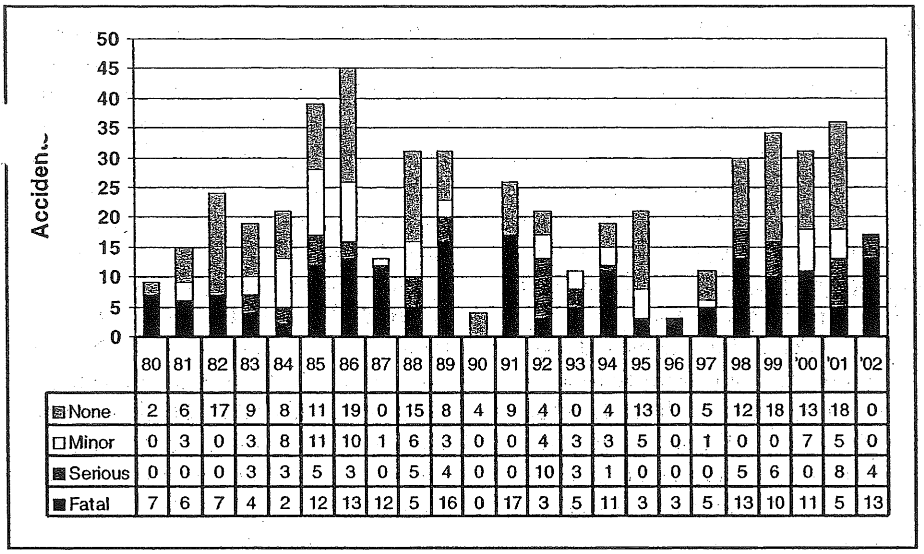


Figure 1–1: HEMS Accidents and Fatal Accidents, 1972–2002*
(*through 9/30/02)



	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	'00	'01	'02
▨ None	2	6	17	9	8	11	19	0	15	8	4	9	4	0	4	13	0	5	12	18	13	18	0
☐ Minor	0	3	0	3	8	11	10	1	6	3	0	0	4	3	3	5	0	1	0	0	7	5	0
▩ Serious	0	0	0	3	3	5	3	0	5	4	0	0	10	3	1	0	0	0	5	6	0	8	4
■ Fatal	7	6	7	4	2	12	13	12	5	16	0	17	3	5	11	3	3	5	13	10	11	5	13

Figure 1–2: Fatalities and Injuries, 1980–2002* (*as of September 30, 2002)

AIR MEDICAL ACCIDENTS: A 20-YEAR REVIEW

Perhaps the most complete analysis of air medical accidents is represented in a series of *AirMed* articles by Rick Frazer. The first of the series was published in the September/October 1999 issue. The article "Air Medical Accidents—A 20 Year rch for Information" presents a review 4 rotor-wing, 15 fixed-wing, and three public EMS accidents for a total of 122 accidents between 1978 and 1998. Included were only accidents that occurred to dedicated medical transport services, not to private or public aircraft that may also perform an occasional medical transport.

This study included only accidents as defined by the NTSB. In follow-up to this article, Frazer looked at specific types of accidents—those related to weather, collisions with objects, and maintenance.

Accidents and Fatal Accidents

While the number of HEMS accidents is a critical consideration, even more important is the high number of fatal accidents seen in HEMS. In the 1980s, 42% of all accidents resulted in at least one fatal injury. Between 1990 and 1998, this percentage rose to 56%. Figure 1–3 compares the number of accidents to fatal idents for 1978 through 1998—the years included in Frazer's report. It is important to note that these numbers do not necessarily correspond to the number of accidents previously presented since this study also included over a dozen fixed-wing accidents and several accidents that did not meet our inclusion criteria.

Severity of Injury

Frazer reported that 406 individuals were involved in HEMS accidents. There were 168 fatalities, 50 serious injuries, and 61 minor injuries. There were 127 who sustained no injury. Figure 1–4 shows the trend over the years with regard to fatalities and Figure 1–5 summarizes the severity of injuries for all the reported accidents.

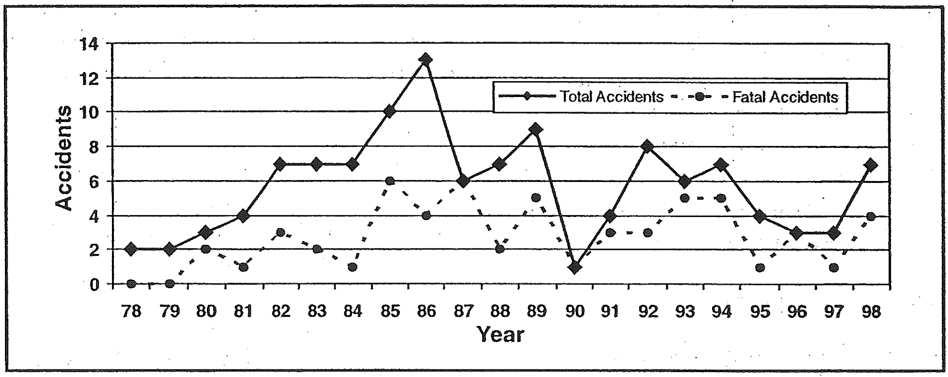


Figure 1–3: Accidents and Fatal Accidents, 1978—1998

Adapted from: Frazer, AirMed, Sept/Oct 1999

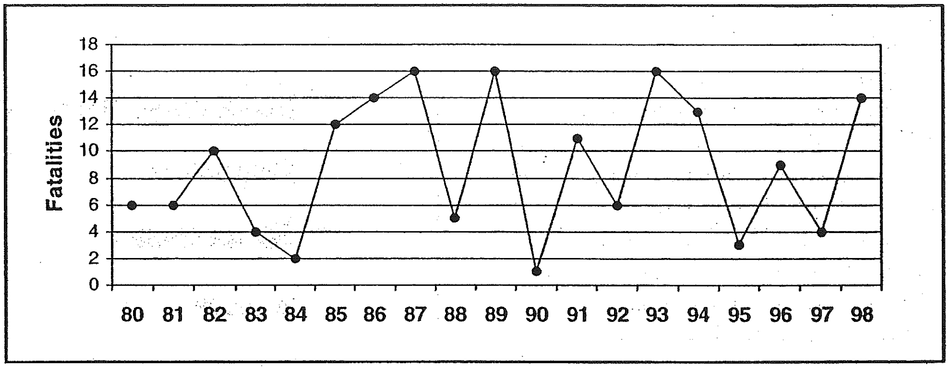


Figure 1–4: Fatalities per Year

Adapted from: Frazer, AirMed, Sept/Oct 1999

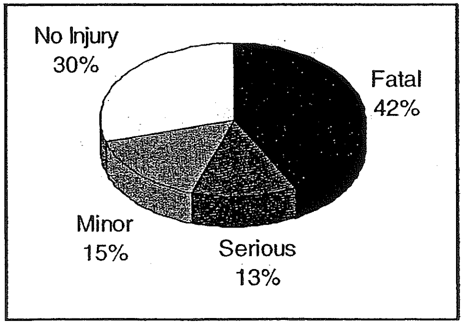


Figure 1–5: Severity of Injuries — Air Medical Accidents, 1980—1998 (n=397)

Adapted from: Frazer, AirMed, Sept/Oct 1999

When Do HEMS Accidents Occur?

When an accident occurs is an impor-nt consideration when looking at the safety of flight and may provide insight to the severity of injuries and the high number of fatalities. The time of day (i.e., day vs. night), type of mission (i.e., the purpose of the HEMS flight), and the phase of flight are all-important factors to evaluate.

Condition of Light

It would appear in Figure 1–6 that EMS accidents showed no significant preference for day vs. night operations. However, the 1999 *AirMed* Transport Survey indicates that only 38% of all HEMS flights were at night. Since 1988, the range has been between 35 to 42%, with an average of 38%. In contrast, 49% of the HEMS accidents over 20 years occurred during night operations. Of interest, Frazer's report identifies three noticeable peak accident times: noon to 1pm, 6–7pm, and 10–11pm.

Phase of Flight

The phase of flight that the aircraft was in at the time of the accident is reported in the NTSB reports. This includes takeoff, landing, cruise, hovering, maneuvering, or taxiing. Data for both helicopter and fixed-wing accidents are provided in Figure 1–7.

As previously mentioned, in most aviation operations, aircraft are more prone to incidents or accidents during takeoffs and landings. This was not found to be the case with HEMS accidents. More accidents occurred during cruise (36%) than any other phase of flight. Accident reports frequently identify entry into inadvertent instrument meteorological conditions (IMC) as a contributing factor for many of the accidents (i.e., flying into poor weather conditions).

Purpose of Flight

The purpose of flight for HEMS accidents was tracked by Frazer in his article. He divided flights into two major cate-ories: patient-related and non-patient related. He further divided the patient flights into scene vs. interhospital; and finally determined if the aircraft was enroute to the patient, had a patient on board, or if the aircraft was returning from a patient flight (i.e., the third "leg" of a transport). Evaluating these components of HEMS transports might indicate a particular interval when more accidents seemed to occur. Figure 1–8 depicts the various purposes of flight and the different legs of patient transport.

Trying to determine the most dangerous flight or leg of a patient transport from Figure 1–8 may be difficult. More accidents occur on the transport to the patient than on either remaining leg. However, if the helicopter was transporting the patient back to its base facility, there would be no third leg of a transport. The pie charts in Figures 1–9 to 1–12 look at the percentage of accidents that occurred on the various types of missions and then each leg of the transport.

In general, it appears that approximately 50% of all accidents occur enroute to the patient and 50% on the way back. Of note is the fact that 85 of the 104 HEMS accidents that occurred were on patient-related missions, of which 36 were scene responses. This corresponds to 42% of the accidents during patient-related missions. Referring again to the "2000 Annual Transport Statistics," scene missions accounted for only 28% of all patient transports. Since 1988, the percentage of scene response flights has ranged from 25% to 36%, with an average of 31%. If all missions had equal risk, then 31% of the accidents should have been on scene missions. Scene missions have always been perceived as the most difficult and potentially the most dangerous in HEMS and this data would seem to confirm this. However, the fact that a higher percentage of the accidents occur after the patient has been picked up rather than enroute to the scene (56% to 44%) further confounds this theory.

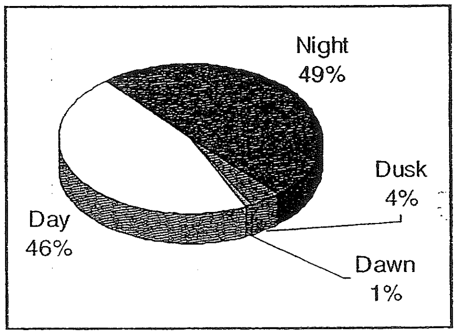


Figure 1–6: Day vs. Night HEMS Accidents, 1978–1998 (n=107)
Adapted from: Frazer, AirMed, Sept/Oct 1999

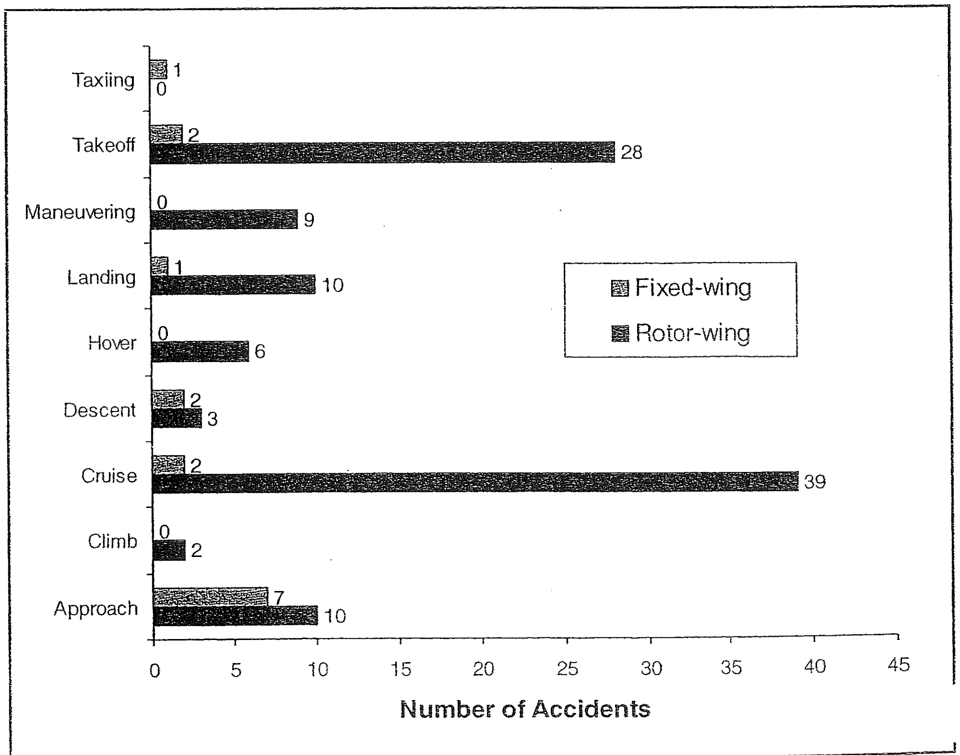


Figure 1–7: Phase of Flight *Adapted from: Frazer, AirMed, Sept/Oct 1999*

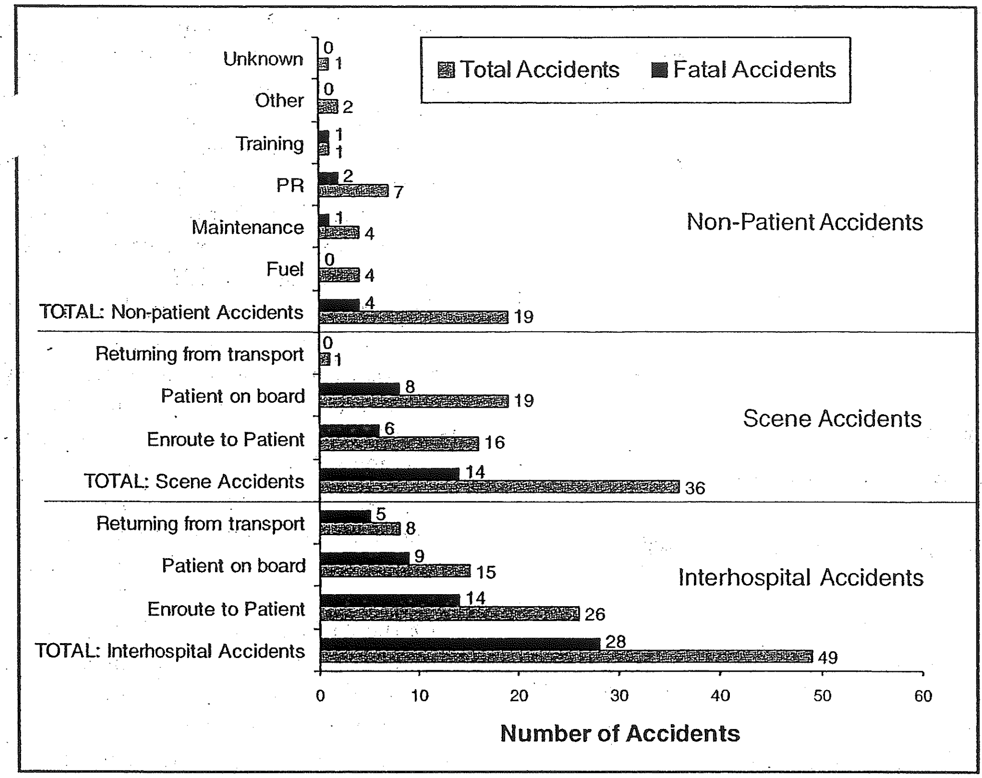


Figure 1–8: Phase and Purpose of Flight

Adapted from: Frazer, AirMed, Sept/Oct 1999

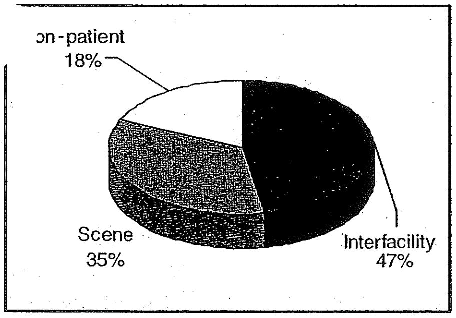


Figure 1–9: All HEMS Accidents (n=104)

Adapted from: Frazer, AirMed, Sept/Oct 1999

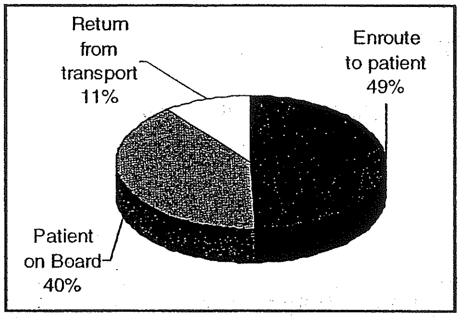


Figure 1–10: Accidents During All Patient Transports (n=85)

Adapted from: Frazer, AirMed, Sept/Oct 1999

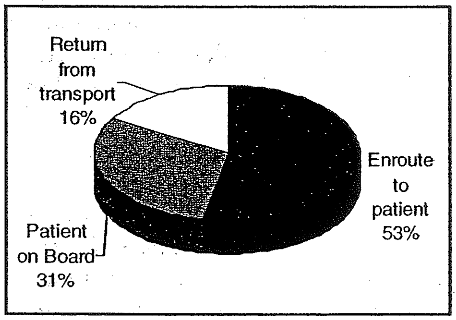


Figure 1-11: Accidents During Interhospital Transports (n=49)

pted from: Frazer, AirMed, Sept/Oct 1999

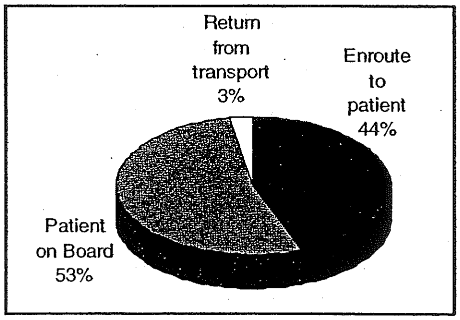


Figure 1–12: Accidents During Scene Transports (n=36)

Adapted from: Frazer, AirMed, Sept/Oct 1999

The Cause of HEMS Accidents

It is rare that a single isolated event causes an accident. Instead, it is generally agreed that a set of contributing factors and circumstances usually lead to a final event that results in the accident. The NTSB investigations, however, usually conclude that an accident occurred as a result of one of two probable causes—either pilot error or mechanical problem. The NTSB may also list the case as "Unknown" or "To be Determined." At times, the NTSB may list more than one cause for a particular accident.

Identifying and specifying the cause of an accident may not be easy, even after a thorough and detailed investigation. In one HEMS accident, after an engine problem developed, the pilot shut down the wrong engine. The result was a fatal accident. Should this accident be attributed to pilot error or a mechanical failure?

The two main categories—pilot error and mechanical failure—are divided into more specific causes as determined in the final report of the NTSB. In his report, Frazer listed the causes of 104 helicopter accidents. A total of 68 (65%) were pilot error and 26 (25%) were mechanical failure. The remaining accidents were unknown (3) or still to be determined (9). Figure 1–13 lists the identified causes of the rotor-wing accidents.

Weather-related Accidents

Weather-related accidents remain an all too familiar theme in HEMS. Frazer's 1999 report listed 23 such accidents, of which 17 were fatal. In the May/June 2000 issue of *AirMed*, Frazer's article "Weather Accidents and the Air Medical Industry" updated his weather-related accident data. With this article, Frazer's accident database has increased from 122 to 136 helicopter and fixed-wing accidents, with 121 final reports available. There are now 31 weather-related accidents in his database, equal to 26% of the accidents with final reports. Of these 31 accidents, 25 were rotor-wing and 6 were fixed-wing.

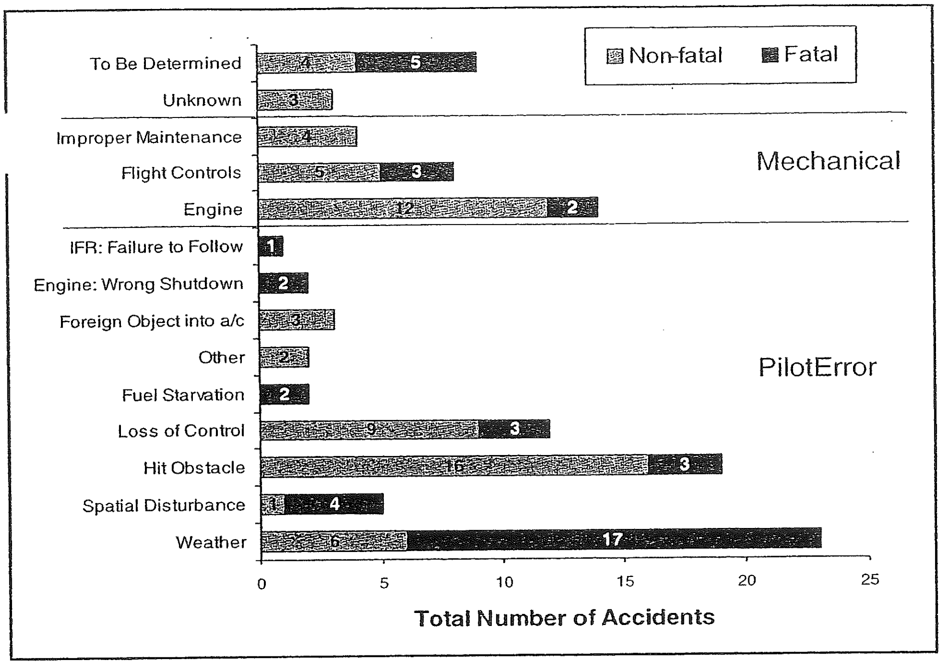


Figure 1–13: HEMS Accidents by Cause *Adapted from: Frazer, AirMed, Sept/Oct 1999*

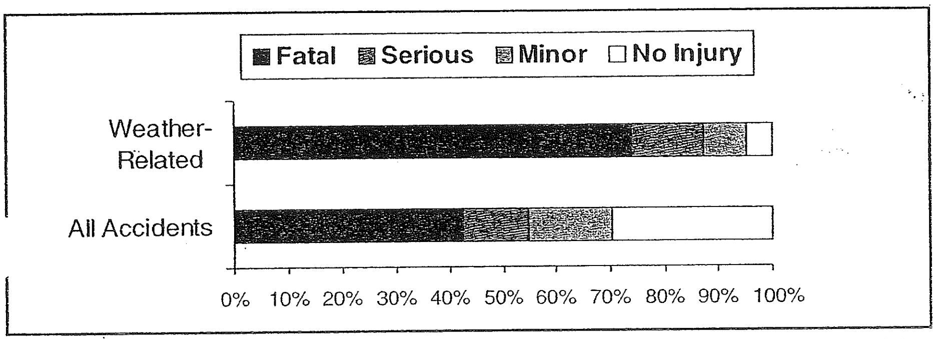


Figure 1–14: Severity of Injuries–All Accidents vs. Weather-related, 1982–1998
(All accidents: n=397; Weather-related accidents: n=103)
Adapted from: Frazer, AirMed, Sept/Oct 1999 and Frazer, AirMed, May/June 2000

Background Information: Weather Limitations

Subpart D of the FAA Part 135 regulations (sections 135.201 to 135.205) outlines the FAA's operating limitations and weather requirements, including minimum altitudes and visibility for "air taxis." In addition, the Federal Aviation Regulations (FARs) under Part 135 require that Air Taxi Operators set their own weather minimums in Chapter 4 of their Operations Manual. The weather minimums describe the minimum ceiling (lowest cloud height above the ground that covers 5/8 or more of the sky) and the minimum visibility the pilot must have to accept a flight.

The ceiling and visibility requirements generally vary for day vs. night flight and for local vs. cross-country flights. The definition of "Local" may also vary from 50 to 100 miles or more. Many state regulatory agencies and organizations may also set minimums for ceiling and visibility. The Commission on Accreditation of Medical Transport Systems' weather guidelines are:

Condition	Area	Ceiling	Visibility
Day	Local	500'	1 mile
Day	Cross Country	1000'	1 mile
Night	Local	800'	2 miles
Night	Cross Country	1000'	3 miles

In the 1980s, there were a total of 73 accidents, of which 16 (22%) were determined to be weather-related. In the 1990s the number of accidents (with final reports) had decreased to 44, with 14 (32%) related to weather. Tragically, while the total number of accidents went down, the percentage of weather-related accidents increased by 10%.

Looking at when these weather-related accidents occur is also of importance. Previously it was noted that nearly half of all HEMS accidents occurred at night (53 of 107). In comparison, Frazer's article in 2000 found that 22 of 25 (88%) weather-related HEMS accidents occurred at night. Fixed-wing weather-related accidents remained at 50%, even at night.

Of the 25 weather-related helicopter accidents, 17 (68%) of the accidents were interhospital and 8 (32%) were scene missions. This correlates well to the overall percentage of scene missions for HEMS program, which was previously noted at 31%. Of interest, there is a noted decrease in the percentage of scene accidents when comparing weather-related accidents (32%) to all patient-related mission accidents (42%).

The outcome of weather-related accidents is also very dramatic. Nineteen of the 25 HEMS accidents (76%) had fatalities and 64% had no survivors. Compared to all accidents in Frazer's 1999 study, only 45% (55 of 122) of all accidents resulted in at least one fatality. In addition, 76 of 103 (74%) of the souls on board sustained fatal injuries, 14 had serious injuries, 8 suffered only minor injuries, and 5 had no injury. Figure 1–14 shows the relative comparison (percentage) of the severity of injuries in the weather-related accidents reported in 2000 to the total accidents reported by Frazer in 1999.

In general, the cause of the weather-related accidents does not appear to be a pilot's disregard for established weather minimums at takeoff. Instead, it is the pilot's encounter with instrument meteorological conditions (IMC) en route. In the narratives of the 25 helicopter accidents, Frazer noted that 10 pilots were turning around, one was circling, six con tinued into IMC and one was on an IFR flight plan. The pilots' actions were unknown in 7 cases.

There are three types of weather-related accidents:

- ***Controlled Flight Into Terrain*** (CFIT) fers to an event that normally occurs in IFR conditions or at night. Loss of situational awareness is apparent in all CFIT accidents.
- ***Loss of Aircraft Control*** corresponds to an event in IFR conditions when the pilot is unable to maintain control of the aircraft by reference to the flight instruments. Spatial disorientation is the primary cause and is often the result of continued VFR flight into IFR conditions.
- ***In-flight Collision with an Obstacle*** is an event that normally occurs in conditions of restricted visibility when the pilot is unable to see an obstacle or the terrain in time to avoid a collision. This is the most common weather-related accident for helicopters.

Collision with Objects

An in-flight collision with an object (CWO) may occur in various conditions settings. Frazer's 1999 study identified HEMS accidents that resulted from a CWO. In his 2001 report "Air Medical Accidents Involving Collisions with Objects," the database increased from 122 to 150 fixed-wing and rotor-wing accidents, 27 of which involved a CWO. This represented a dramatic increase in the number of CWO accidents, as there had been a total of 8 such accidents during the 9-year period from 1990 to 1998, while in 1999 and 2000 alone, there were 7 CWO accidents. Frazer also identified 21 CWO incidents over the past 5 years.

Twenty-five of the CWO accidents in Frazer's report involved rotor-wing aircraft. Frazer observed that weather was not considered to be a factor in any of these. Sixteen (64%) of the accidents occurred during scene response missions—all occurring at or near the landing zone. Eight (32%) were during some phase of flight during interhospital transports, four of these at or on the hospital helipad. The remaining CWO was during a maintenance flight. Of the 24 patient mis- s, 12 occurred on the way to pick up the patient, 9 occurred with the patient on board, and 3 were returning after a patient flight. As previously presented, scene response flights account for an average of 31% of all patient transports. If all missions had equal risk, 31% of the CWO accidents should have been on scene missions. Instead that percentage more than doubles.

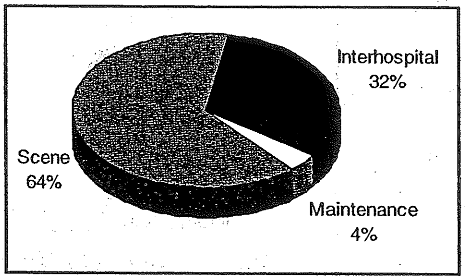


Figure 1–15: Type of Mission—CWO Accidents (n=25)

Adapted from: Frazer, AirMed, May/June 2001

Wires are the most common objects with which helicopters collide. Of the 25 CWO accidents, 9 were wire strikes. Frazer classified four of the CWO accidents as "other," which included the ground, rocks, and in one incident, a barge. There were three CWOs with trees, three with ground obstacles (lamp posts, fencing, etc.), two with support cables to towers and one each with a building, hangar, hospital helipad, and tower.

As expected, collisions with objects occur most commonly on takeoff and landing. The time of day also varies, but yielded some interesting results as seen in Figure 1–16.

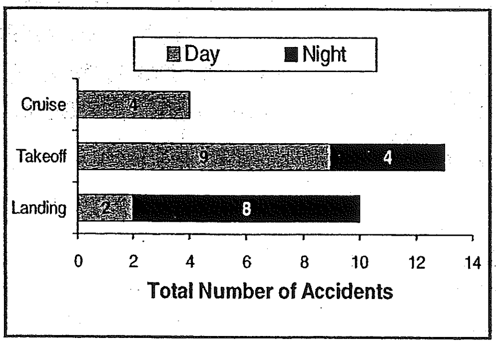


Figure 1–16: Phase of Flight and Lighting Conditions

Adapted from: Frazer, AirMed, May/June 2001

Since most of the CWO accidents occur during takeoff and landing, it follows that the aircraft are at a lower altitude and slower speed.

Accordingly, only 7 of the 25 (28%) RW accidents resulted in a fatality. Of the 4 cruise accidents, 3 were fatal. All the cruise CWO accidents identified by Frazer were RW, all were during the day in clear weather, and 3 were on the return flight home.

Frazer concludes his 2001 study with recommendations for comprehensive training and procedures for flight personnel to enhance safety and reduce the likelihood of CWO accidents. "Medical personnel should be taught how to spot obstacles, and detailed procedures should be in place on how to communicate—down to the exact words the crew uses—an immediate threat versus an obstacle in the distance." In addition, Frazer suggested the disassociation of Landing Zone (LZ) and safety training from marketing and emphasize the importance of ongoing safety education as a separate, budgeted activity.

Maintenance-related Accidents

The data presented in Figure 1–13 represent Frazer's 1999 study, which showed 26 maintenance-related accidents (MRAs) out of 122 total accidents. In the May/June 2002 *AirMed*, Frazer examined the "Air Medical Accidents Attributed to Maintenance." A total of 34 such accidents were identified in the 2002 report which now includes 143 rotor-wing and 18 fixed-wing MRAs. Thirty of the MRAs were rotor-wing and four were fixed-wing. Excluding 11 accidents that lacked NTSB final reports, Frazer concluded that 23% of all accidents were maintenance-related.

Frazer separated the probable cause of the MRAs into five different categories. Over the 24-year period, there were a total of 17 engine-related accidents, 15 of which involved rotor-wing aircraft. Twelve involved single-engine aircraft and three involved twin-engine aircraft. Even though the engine-related accidents represent half of all MRAs, Frazer observed that engine-related *incidents* happen much more frequently. Fortunately, due to the skills of the EMS pilots, the vast majority of these incidents do not result in accidents.

In 11 of the final NTSB reports, Frazer found nadequate or improper maintenance" as a fac- r in the accident. In addition, there were five reports that identified "manufacturer design" or "inadequate aircraft component product/design" as a factor.

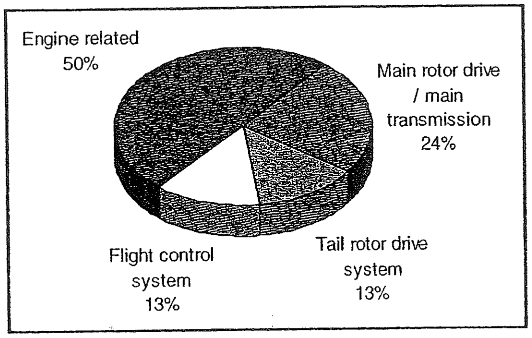


Figure 1– 17: Probable Cause of Maintenance-related HEMS Accidents (n=30)

Adapted from: Frazer, AirMed, May/June 2002

As Figure 1–18 shows, nearly 50% (16 of 34) of all rotor-wing and fixed-wing MRAs occurred during cruise. Interhospital transport accounted for nearly two-thirds of the accidents.

ilot Experience

Experienced pilots don't make mistakes or have accidents. Or do they? Unfortunately, flying with "high-time" pilots does not necessarily guarantee that an accident won't happen. Much of the HEMS industry requires a minimum of 2,000 hours of flight time before assuming command of a medical helicopter. In addition, most operators, organizations, and even some states dictate a specific number of flight hours in type-specific aircraft before a pilot can fly medical missions.

Figure 1–19 shows the flight experience of the pilots involved in HEMS accidents. Unfortunately, there is no data available regarding the average number of flight hours for *all* HEMS pilots or the percentage of all HEMS pilots that would fall into each category listed in Figure 1–19. Of the pilots involved in HEMS accidents, the lowest total hours were 1,432, while the highest was 14,000. More importantly perhaps, in 27 of the 122 accidents (22%), the pilot had fewer than 200 hours of flight time in the make and model of the aircraft they were flying at the time of the accident. Eighteen 15%) had fewer than 100 hours and one had only three hours.

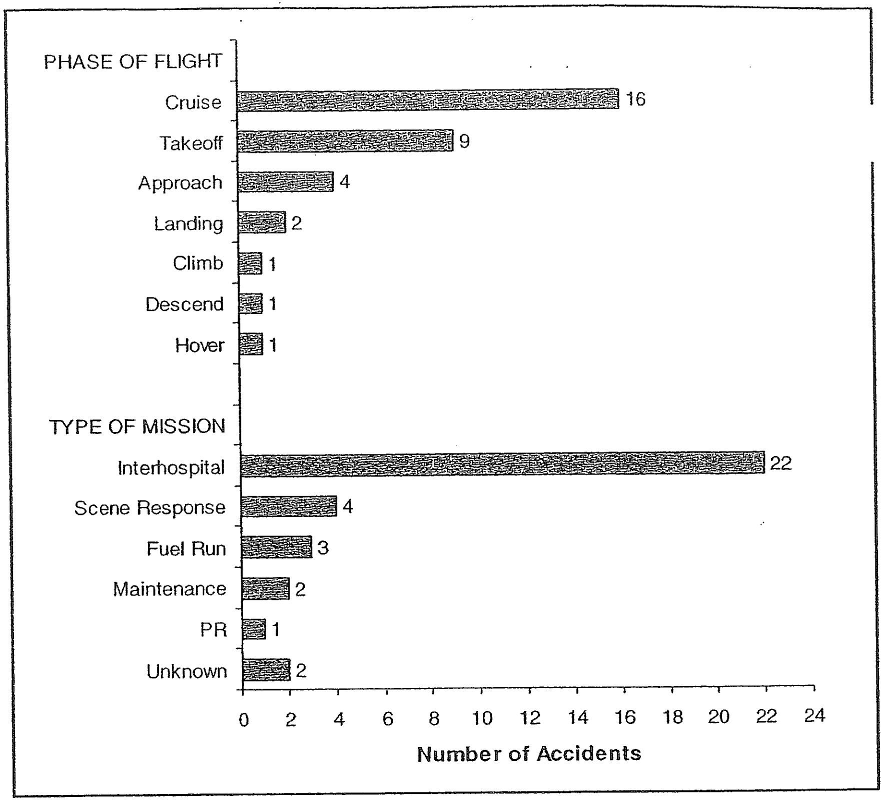


Figure 1–18: Maintenance-related Accidents—Phase of Flight and Type of Mission *Adapted from: Frazer, AirMed, May/June 2002*

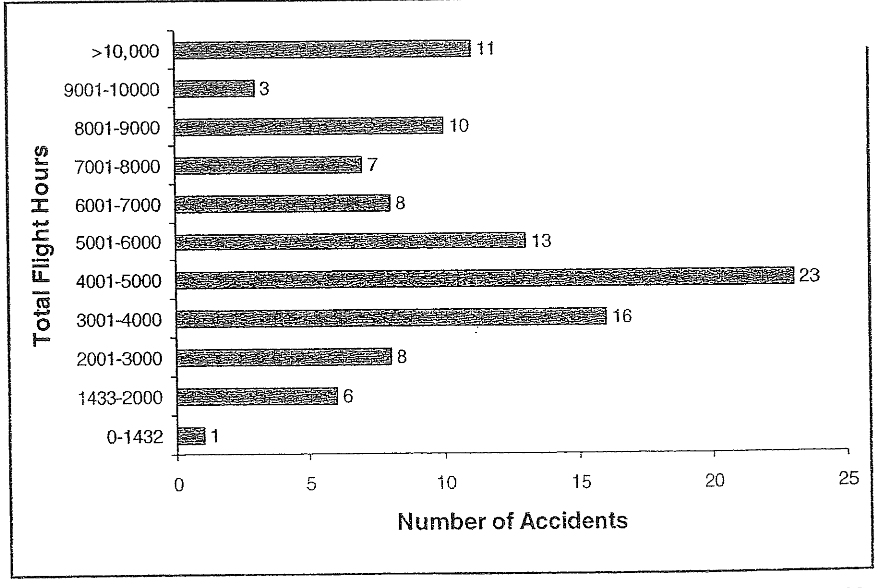


Figure 1–19: Pilot Experience *Adapted from: Frazer, AirMed, Sept/Oct 1999*

Engines

A frequent debate with regard to safety is whether "two engines are better than one." Of the 17 accidents attributed to engine problems, 12 were single-engine and 3 were twin-engine. However, this does not help resolve the debate, knowing that in the early years of HEMS, most helicopters were single-engine. Therefore, more of the accidents were in single-engine aircraft. In another section of this report is accident data collected by the Helicopter Association International (HAI) comparing single- vs. multi-engine helicopters which shows a lower accident rate overall for multi-engine helicopters.

Aircraft Damage and Post-Impact Fire

In the NTSB accident reports, aircraft damage is classified as either destroyed or substantial. Of the 122 air medical transport accidents, 70 (57%) aircraft were destroyed and 51 (42%) were reported as having suffered substantial damage. At the time of Frazer's report, one was listed as unknown. Of note, when looking only at the weather-related accidents, 84% of the helicopters and 100% of the fixed-wing aircraft were destroyed.

Post-impact fire is often perceived as another major concern with regard to HEMS accidents. Frazer's data, seen in Figure 1–20 shows that the vast majority of HEMS accidents do not result in a post-impact fire. While fixed-wing aircraft accidents resulted in fires 67% of the time, only 15% of helicopter accidents sustained post-impact fires. There were, however, six accidents that had an in-flight fire.

NATIONAL TRANSPORTATION SAFETY BOARD SAFETY STUDY: COMMERCIAL EMERGENCY MEDICAL SERVICE HELICOPTER OPERATIONS – 1988

Frazer's 20-year review provides a comprehensive look at the HEMS industry and our accident history from 1978 to 1998. This next report by the National Transportation Safety Board (NTSB), however, looks at a narrower time frame. When published in 1988, it became the hallmark safety study at the time of our industry's highest accident and fatality rate.

During the early 1980s, the increased use of helicopters as air ambulances came at a high price. While the number of flight programs more than tripled from 1981 to 1986, the NTSB began to identify a significant rise in the number of accidents. In 1984 there were 7 HEMS accidents. The next year, there were 11 and in 1986, there were 14 accidents investigated by the NTSB. These 14 accidents corresponded to 9 percent of the total commercial HEMS industry operating that year. As a result, a formal safety study was undertaken by the NTSB and published in 1988.

The NTSB studied 59 commercial HEMS accidents that occurred between 1978 and 1986. Nineteen of these accidents resulted in fatalities, taking the lives of 53 people (19 pilots, 28 medical personnel, and 6 patients). A total of 47 accidents were on patient mission flights and 12 while on other activities (refueling, PR, training, etc.). However, in the calculation of accident rates, the NTSB only included the 47 "mission" accidents. In addition, this study did not include any public-use aircraft.

According to the NTSB report, from 1980 through 1985, HEMS had an estimated accident rate of 12.34 accidents per 100,000 hours of flight, nearly double that of nonscheduled Part 135 ("air taxi") helicopter operations (6.69/100,000 flight hours). They also determined that the fatal accident rate for HEMS was 5.40—nearly 3.5 times higher than the 1.60 determined for other nonscheduled Part 135 helicopter operations.

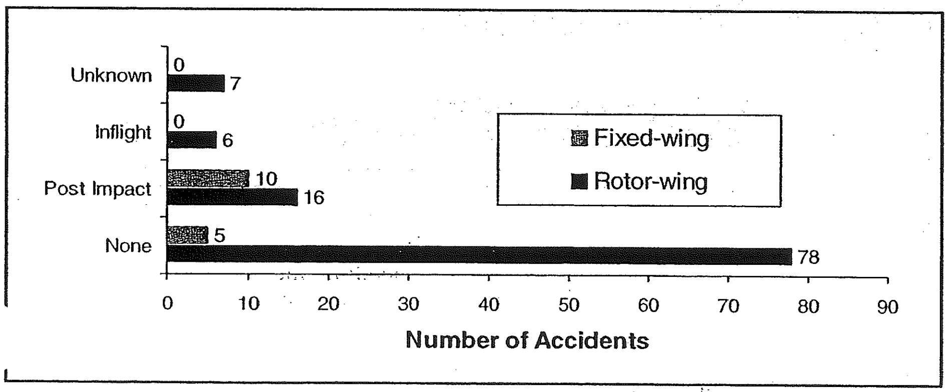


Figure 1–20: Air Medical Accidents with Fires *Adapted from: Frazer, AirMed, Sept/Oct 1999*

The NTSB identified four major factors in the 59 HEMS accidents studied. Human error (i.e., pilot error) was attributed as the cause, directly or indirectly, of the majority of these accidents (68%). Weather was the second most common cause of these HEMS accidents (30%), followed by mechanical failure (25%), and obstacle strikes (20%). The weather-related accidents accounted for 61% of the fatalities and the NTSB concluded that poor weather poses the greatest single hazard to EMS helicopter operations.

The NTSB report identified several disturbing trends involving HEMS operations. They were concerned that the rapid increase in the number of programs and resulting competition could result in a focus on transport volume instead of flight safety. Pilots might feel self-imposed or externally imposed pressure (i.e., by management) to accept and complete flights despite marginal operating conditions. In addition, pilot training was often deficient in interpretation of weather conditions and in instrument flight procedures. They also found that modified EMS interiors and various program practices often compromised crashworthiness standards, resulting in an increased risk of injury and death.

The NTSB report ended with specific recommendations—some to the FAA and some to the American Society of Hospital-Based Emergency Air Medical Services (ASHBEAMS, which changed its name in 1989 to the Association of Air Medical Services). Included in these recommendations were: improved interior modifications that would not compromise crashworthiness; the use of shoulder harnesses and protective clothing (e.g., helmets, flame-resistant suits, protective footwear); the development of program safety committees; improved training in a number of areas, including marginal weather operations, emergency procedures, pilot-crewmember coordination, and communications.

In reviewing the NTSB data an interesting observation is made with regard to inclusion criteria and selection. A 1986 Chicago accident is included that did not involve a medical helicopter, but a corporate helicopter that suffered a tail rotor strike upon departing a hospital helipad after dropping off a passenger. The NTSB, however, chose to include this as a medical helicopter accident even though, in this author's opinion, the helicopter did not meet the NTSB inclusion criteria (aircraft dedicated to the EMS mission, has trained medical personnel on board, and the pilot is employed primarily to fly dedicated EMS missions).

The NTSB report identifies a total of 88 accidents that occurred during their designated study period (1978 through 1986). Based upon their inclusion criteria, the study group was reduced to the 47 "mission" accidents. The "Industry Reported EMS Accidents" came from six different reporting sources and their respective databases: American Society of Hospital-Based Emergency Air Medical Services (ASHBEAMS, now AAMS), Aviation Safety Institute, Hospital Aviation Magazine, FAA Accident/Incident Data System, National Emergency Medical Services Pilots Association (NEMSPA), and the NTSB Accident database.

FLIGHT SAFETY FOUNDATION: HUMAN ERROR AS MAJOR CAUSE OF U.S. COMMERCIAL EMS HELICOPTER ACCIDENTS

Patrick Veillette, Ph.D., studied a total of 87 HEMS accidents and 56 incidents from January 1987 through December 2000. Of interest, Veillette's 2001 study and his database begin where the 1988 NTSB report concluded.

Much like Frazer's studies, this comprehensive report analyzes many common factors related to HEMS accidents, including phase of flight, weather-related accidents, collisions with obstacles, and mechanical-related accidents. Veillette, however, also presents his findings regarding human error as a major factor in HEMS accidents. His discussions also include the findings of numerous other safety reports, FAA Advisory Circulars, and publications.

Veillette concluded that human error was associated with 66 of the 87 (76%) HEMS accidents studied. Of the fatal accidents studied, human error was associated with 84% (27 of 32). Recurring human error factors identified and the number of accidents for which they were cited is shown in Figure 1–21.

Veillette also reviewed the effect human error had on the various phases of flight accidents. He found that human error accounted for 68% of the en route accidents, 91% of the accidents during approach and landing, and 82% of the accidents during takeoff. Of the approach and landing accidents, 41% were due to a collision with an obstacle, while 50% of the takeoff accidents were collisions with obstacles. Figure 1–22 shows the most common phase of flight accident categories.

As mentioned, Frazer and Veillette have reviewed many of the same characteristics surrounding HEMS accidents. Although their findings are similar, several differences are noted. Since the NTSB database was the major source for both studies, the variations must take into account the different years each author included in their study and the fact that Frazer also included fixed-wing accidents. Veillette's review of 1987–2000 excluded many of the years with the highest number of HEMS acci-

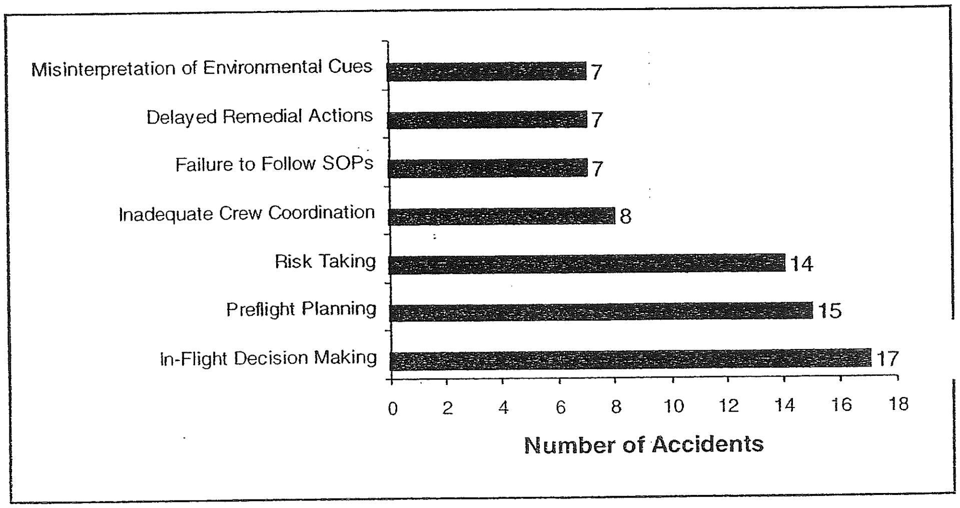


Figure 1–21: Human Error Factors in HEMS Accidents, 1987–2000

Adopted from: Veillette, Flight Safety Digest, April/May 2001

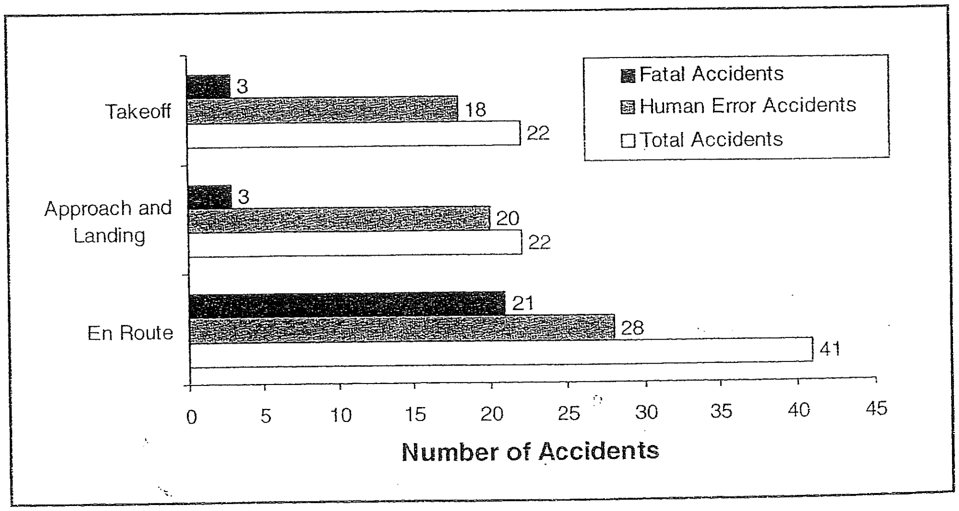


Figure 1–22: Phase of Flight Accidents, 1987–2000

Adopted from: Veillette, Flight Safety Digest, April/May 2001 dents (1982–1986) that were included in Frazer's study. However, Veillette may have been able to identify any significant nds that may have changed *after* the n number of accidents of the early '80s.

Frazer's 2001 study found that 18% of the accidents were the result of collisions with obstacles, while Veillette's report identified 31%. Another difference noted was with regard to aircraft damage and post-impact fires. In Frazer's study of 122 aircraft accidents, 57% were destroyed and 42% had substantial damage. Veillette's data is nearly reversed, with 41% destroyed and 59% sustaining substantial damage. Frazer also found that 15% of the helicopter accidents resulted in a post-impact fire, while Veillette study found less than 6% resulted in a fire.

Veillette identified 47% of accidents occurring en route compared to 36% in Frazer's study. This difference, however, could be due to the number of categories identifying the various phases of flight. Veillette listed only 5 categories (takeoff, en route, maneuvering, approach and landing, ground), while Frazer listed 8 teoff, cruise/en route, maneuvering, pproach, landing, hover, descent, climb). Finally, as previously noted, Veillette found 76% of the accidents to be associated with human error, while Frazer's study found this to be 65%.

Veillette made several references to the crew in his analysis of the accident database. He found that inadequate crew coordination was cited in eight accidents. Each of these accidents involved a collision with obstacles that occurred during takeoff or landing. Other factors included incorrect or untimely information and distracting comments or movements by the medical crew during a critical phase of flight. He also cited four accidents and six incidents that were caused by cowlings and panels that separated from the helicopter. In half of these events, the medical crew had closed the cowlings improperly prior to flight.

Unique to this study, Veillette reports on his personal observations made during ore than 400 HEMS transports ween 1995 and 2000. His observations were categorized by the type of flight—scene response (128), interhospital transfer (58), and repositioning (247). It was not mentioned if these observation flights were all with the same program or with different programs. Veillette observed that during none of the transports was the medical crew wearing helmets, while the pilots wore helmets more than 70% of the time. The author did not mention whether helmets were available to the medical crew or to all of the pilots.

Most surprising was his observation regarding the use of seat belts and shoulder harnesses by the medical crew. In 100% of the repositioning flights, the medical crew was wearing seat belts during takeoff, but only 45% were wearing shoulder harnesses. However, on takeoff from scene responses, only 11% were observed to be wearing seat belts and only 4% had shoulder harnesses fastened. The percentage was even lower on takeoff from interhospital transfers, with seat belts buckled only 6% of the time and shoulder harnesses only 4%. While this would appear to be a serious breech of routine safety protocols, Veillette only comments that "because of their in-flight medical duties, medical crewmembers frequently are not seated in energy-absorbing seats with their seat belts and shoulder harnesses fastened."

Veillette's article concludes with a complete listing of the accidents and incidents included in his database. In this same issue of *Flight Safety Digest*, Veillette offers a second comprehensive study that specifically addresses EMS airplane accidents. This second article, which spans 1983–2000, may be the most complete analysis of fixed-wing air medical accidents available. Both of these articles provide excellent information and detailed insight into various aspects of air medical accidents.

EMERGENCY MEDICAL SERVICE HELICOPTERS INCIDENTS REPORTED TO THE AVIATION SAFETY REPORTING SYSTEM

All too often, helicopter accidents include pilot fatalities. Many of these accidents do not provide investigators with adequate and complete information as to the chain of events that led to the accidents. With the high number of fatal HEMS accidents, information from alternative perspectives could be helpful to identify potential problems and prevent future accidents. One such perspective is reports of aviation incidents that did not result in accidents. The U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) has the world's largest database on aviation incidents and serves as an important resource for this alternative perspective.

The NASA-Ames Research Center searched the ASRS database for reports related to EMS helicopter incidents. From 1986 through 1991, 68 of 81 HEMS incident reports were considered relevant and were included in their study. These reports, which were voluntarily submitted by EMS helicopter pilots, air traffic controllers, and pilots of other aircraft, (i.e., anyone who observes an incident) often included the crucial "chain of events" and the successful resolutions of the incidents. The benefit of these reports was that they enabled the pilot to report what he/she was thinking at the time of the incident.

The objectives of the Ames study were to: (1) identify the types of safety-related incidents reported to ASRS in EMS helicopter operations; (2) describe the operational conditions surrounding these incidents, such as weather, airspace, flight phase, and time of day; and (3) assess the contribution to these incidents of selected human factors, such as communication, distraction, time pressure, workload, and flight/duty impact.

The type of information obtained from the ASRS incident reports and their narratives is very different from the type of accident data already presented. The data were evaluated according to incident variables, operational variables, and human factor variables.

Incident Variables

The Ames report found that nonadherence to the Federal Aviation Regulations (FARs) was identified in 53% of these reports. This included violations of flight/duty limitations, maintenance requirements, and so on. Airspace violation ranked second (23%). Conflict or near-midair collision (NMAC) and in-flight encounter with instrument meteorological conditions (IMC) were reported in 14% of the reports. It should be noted that 22% of the reports identified problems that could not be specifically addressed by other incidents. Figure 1–23 lists the anomalies reported in the ASRS reports.

Operational Variables

This category includes phase of flight, weather conditions, time of day, and type of airspace involved at the time of the incident. Most commonly, HEMS incidents occurred during cruise and during good weather. The time of day most often involved was from 1201 to 1800 hours, which generally corresponds with the busiest time of day for flight programs. The reported incidents occurred in all types of controlled and uncontrolled airspace.

In comparing their findings with the 1988 NTSB report, the Ames report found several similarities and one significant difference. The Ames report found that in comparing the two studies, the weather conditions (i.e., unplanned entry into IMC), airspace, phase of flight, and experience levels of the pilots were similar. In addition, the quality and interpretation of weather information was noted as a concern in both studies. In the Ames report, they found that pre-flight weather briefings had been obtained in 80% of the incidents, but 75% of the briefings did not match the actual weather conditions the pilots encountered in flight.

One difference noted between the NTSB and Ames report was IFR currency. In the ASRS study, 68% of the HEMS pilots had an instrument rating and 66% were IFR current at the time of the incident. In contrast, in the NTSB report 86% of the pilots were IFR-rated, while only 6% were IFR current. The Ames report concluded that "this finding appears to be a compelling reason to advocate IFR currency for EMS pilots, although additional research is necessary to reach this conclusion because of the limitations of the ASRS data." The narratives in these ASRS incidents reported that IFR rating and currency were very helpful, if not invaluable.

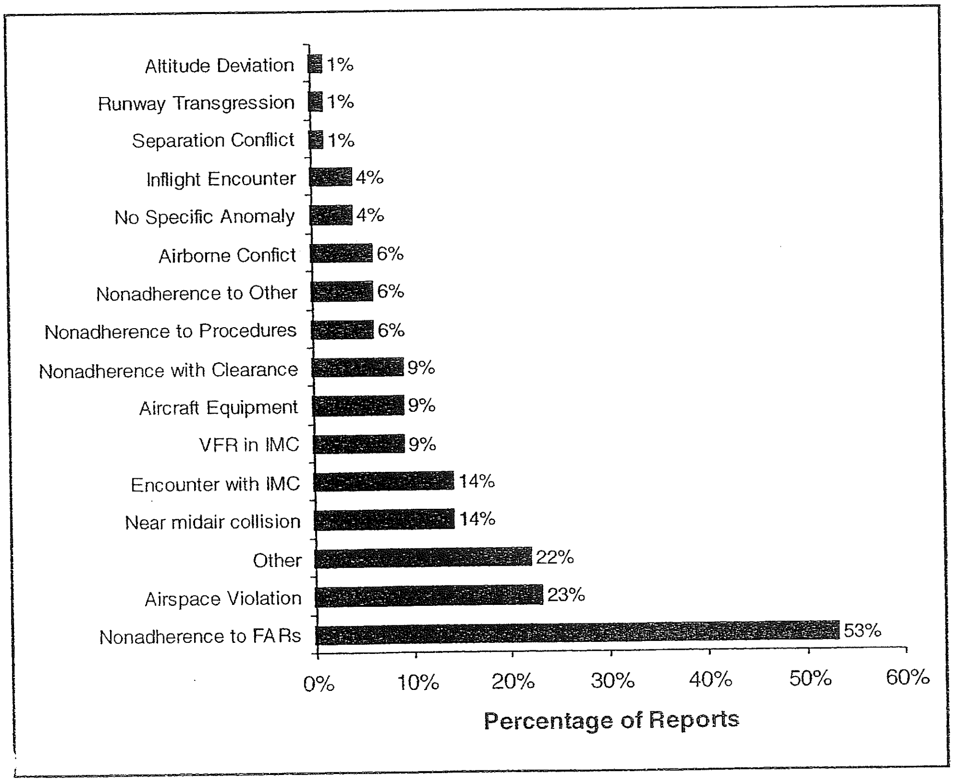


Figure 1–23: Frequency of ASRS Reported Anomalies HEMS, 1986–1991 (n=68)
Adapted from: Connell, Flight Safety Foundation, 1995.

Background Information: Instrument Rating, Currency, and Proficiency

Rating: The FAA defines "rating" as "a statement that, as a part of a (pilot's) certificate, sets forth special conditions, privileges, or limitations." To achieve an instrument rating, a pilot must pass a written test and a flight test given by the FAA. Upon passing these tests, the instrument rating becomes part of the pilot's certificate (license) and the pilot is now legal to fly under instrument conditions for the next six months.

Currency: To maintain currency, a pilot must have flown, within the preceding six months, at least six (6) instrument approaches in a helicopter, completed holding procedures, and intercepted and tracked courses through the use of navigation systems. The flight experience must be repeated at least every six months to maintain IFR currency.

It is important to note that an IFR flight must be to a location (e.g., an airport or helipad) that has an authorized instrument approach. IFR flight *does not* facilitate travel to the scene of an accident or to most hospitals. Recent technology, however, has enabled dozens of hospitals to develop these instrument approaches.

Proficiency: If a pilot does not meet the instrument experience outlined in "currency" within the prescribed time (i.e., the preceding six months) or within 6 calendar months after the prescribed time, he/she will not be able to fly under IFR conditions until he/she passes an instrument proficiency check. This must be in an appropriate aircraft (i.e., for helicopter pilots, it must in a helicopter) and must be given by an examiner, a company check pilot, an authorized flight instructor, or an individual authorized by the FAA to conduct instrument practical tests. Once the pilot has passed this check he/she may fly under instrument conditions for the next 6 months.

Human Factor Variables

Concerns related to communications, time pressure, and distractions were rted at very high rates as seen in gure 1–24. In addition, workload and flight/duty conditions were also identified in the ASRS reports.

Communications

Of the communications incidents, 60% involved pilot-air traffic control (ATC) communications. Another 13% were communications problems between pilots and weather services (i.e., poor or inaccurate weather information that became a major contributor to in-flight encounters with IMC). Communication difficulties between pilots, HEMS dispatchers and ground personnel (e.g., police, firefighters, paramedics, ground crew, maintenance) were also reported as a frequent problem, especially if they interfered with ATC communications.

Time Pressure

Time-related pressures were cited as a frequent contributor to the ASRS incits. These pressures centered around r different considerations: patient condition, rapid mission preparation, flight to the patient pick-up location, and low fuel. Patient condition was reported 44% of the time and was the most important contribution to time pressure. The critical condition of a patient could create a sense of maximum urgency. As a result, preflight planning may be inaccurate or preflight inspections and checklist may be hurried and incomplete. Other reports cited such oversights as not stopping for refueling; failure to obtain or review correct charts; overflying scheduled aircraft maintenance; inadequate or less-than-thorough weather briefings; and inadequate evaluation of weather briefings preceding the go/no-go decision. The Ames report found that time pressure associated with the patient's condition seemed to be present regardless of whether the patient was already onboard the aircraft or the pilot was en route to patient pick-up.

Most programs strive to isolate the pilot from knowing any medical information so that their flight decisions are made objectively. Unfortunately, we may not be as successful as we would hope. HEMS pilots are well aware that their services are generally requested when there is a critically ill or injured person in need of transport. In addition, the pilot may be faced with a sense of urgency from both verbal and/or nonverbal signals from the medical crew. One ASRS report stated, "No flight is so important that the lives of the flight crew should be jeopardized due to incomplete or inaccurate preflight planning."

Distractions

Distraction from the primary task of flying the aircraft was reported in many of the ASRS incidents. External factors created many distractions that were cited in the reports. These included in-flight aircraft equipment problems, the need to monitor multiple radio frequencies, traffic avoidance in high-density traffic areas, interruptions, radio frequency congestion, poor visibility due to haze or night operations, marginal weather, noise from on-board medical equipment, and impending low-fuel situations. Many of these distractions could also lead to time-pressure situations.

Internal factors were also reported which led to significant distraction. This included personal or family-related concerns, anxiety in the current situation, disorientation, involvement in patient condition, confusion about procedure, and general inattention.

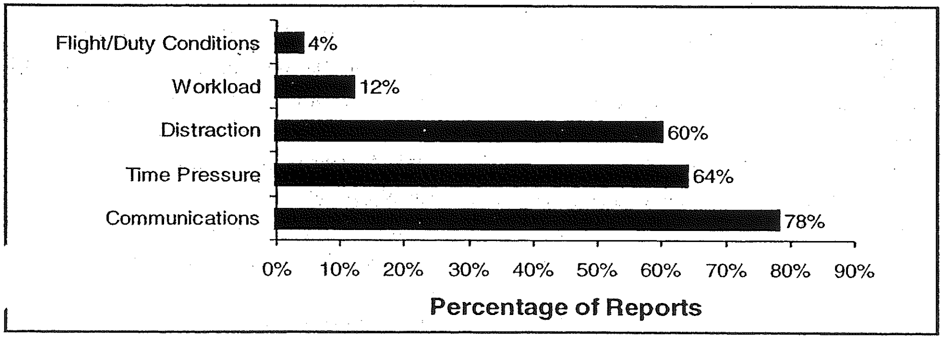


Figure 1–24: Human Factors in HEMS Incident Reports (n=68)
Adapted from: Connell, Flight Safety Foundation, 1995.

Distractions can lead to accidents. In our daily activities, it is common to try to do multiple things at the same time—to multitask. While driving, it seems to make perfect sense to get something else done. Many people use their handheld cellular telephones. There are several recent studies that indicate a strong correlation between the use of cell phones and the increased probability of an auto accident due to the distraction.

Aviation is no different. The idea of the sterile cockpit began in commercial airlines and has been around for years. By eliminating unnecessary talking during critical stages of flight, we can reduce distractions and improve our safety record significantly. Medical crewmembers, patients, passengers, and even other pilots, despite good intentions, can be significant distracters.

Workload and Flight/Duty Considerations

While workload (12%) and flight/duty considerations (4%) were reported in the ASRS incidents, the Ames study concluded that they were not a significant contributor to any HEMS incident.

However, workload, flight/duty length, crew rest, and the number of duty days can influence many factors, including judgment, error recognition, concentration, forgetting tasks, fatigue, and ultimately can lead to aviation incidents.

An unexpected finding in the HEMS ASRS reports was that cruise flight was a common time for HEMS safety incidents. Airspace violations and near-midair collision most frequently occurred in cruise flight and in VFR weather. In-flight weather encounters were also reported as occurring most often in cruise flight. During cruise, it would be anticipated that cockpit activity would be low—unlike takeoff and landing. However, it appears that the HEMS pilot might be attending to tasks inside the cockpit, rather than watching for conflicting traffic, low clouds, or airspace boundaries. These cockpit activities might include providing position reports to dispatch, coordinating with the medical center, programming navaids, or communicating with other EMS personnel.

The Ames report focused on the unique demands placed on the HEMS pilot that led to distraction and time essure. It concluded that these emands could compromise good communications, thorough planning, cooperative teamwork, and safe flight during patient transport. It recommends that steps need to be taken to improve communication, decrease distraction, decrease time pressure to realistic levels, and assist in workload management.

Ames proposed that Crew Resource Management (CRM) was not just for major airlines or big companies. Effective communications among all HEMS team members—pilots, flight nurses, paramedics, doctors, administrators, and communication specialists—are vital if the HEMS team is to perform its duties efficiently, successfully, and safely. CRM will be discussed in more detail in Section 4 of this report.

AIR MEDICAL ACCIDENT ANALYSIS

In April 2000, an Air Medical Safety Summit was convened to address the rising number of air medical accidents. From this Summit of industry leaders and safety experts came the Air Medical Safety Advisory Council (AMSAC), the Air Medical Service Accident Analysis Team and several other initiatives.

The Air Medical Service Accident Analysis Team was created to study past accidents, analyze the root causes of these accidents, and identify effective and feasible interventions that would prevent future HEMS accidents. Chaired by Richard Wright, Jr., of the Helicopter Association International, the main focus of the Team was human factor accidents. It was felt that identified interventions in this area might have the greatest impact on accident prevention and safety.

The Team identified 20 HEMS accidents between November 1993 and November 1999 whose Final NTSB Accident Reports included extensive data for review and evaluation. The process used to examine these accidents is referred to as "root cause analysis."

Event Sequence

A timeline of events was developed for each flight from the available accident report. This included all aspects of the transport, from prior to the flight, during the flight, and ending with the accident itself.

Problem Statements

Any and all "problems" that could have contributed to the accident were then identified. Among the 20 flights, a total of 56 individual problems were identified. They were then classified as: pilot performance issues (23), aircraft issues (9), infrastructure issues (9), environmental issues (6), landing zone issues (5), and corporate and/or program management issues (4), as identified in Figure 1–25.

Intervention Strategies and Ratings

Interventions were next identified for each problem to determine what might have prevented the problem, potentially averting the accident. A total of 65 unique interventions were proposed, which were categorized as Training Interventions, Equipment Interventions, Air Traffic Management Interventions, Regulatory or FAA-sponsored Interventions, National Airspace (NAS) or Infrastructure Interventions, or Miscellaneous Interventions.

Each intervention was evaluated and scored by the Team for its effectiveness, yielding a ranking, or *Effectiveness Score*. The combined score was then divided into thirds to group the interventions that rated *High* (21–17), *Moderate* (16–13) and *Low* (12–8) *Effectiveness*.

The next step was to evaluate and score each Intervention to determine it's technical feasibility, financial feasibility, regulatory feasibility, and operational feasibility. A range from 48 to 13 was obtained for the 65 interventions. As before, the combined scores were then divided into thirds, to rank the interventions as *High* (48–37), *Moderate* (36–32), and *Low* (31–13) *Feasibility*.

Recommendations

The results were combined into a matrix, with interventions classified into nine different categories. It was the Team's recommendation that AMSAC focus efforts within the air medical industry to develop implementation strategies for those interventions that ranked highly effective and highly feasible. Recommended for consideration were those interventions that were identified as highly effective but moderately feasible, highly feasible but moderately effective, and those that were moderately effective and moderately feasible. Interventions classified as low effectiveness and/or low feasibility were not recommended by the Team for implementation or further pursuit. Figure 1–26 lists the nine categories and the Team's recommendations to AMSAC.

This document is an excellent resource that takes a detailed and comprehensive look into the specific problems and events that have led to previous HEMS accidents. The Team has also provided a comprehensive list of specific technologies, training, regulations, and operational enhancements and rankings of their effectiveness and feasibility as interventions that can improve the safety of air medical transport and reduce the number of accidents. However, in making their recommendations, the Team divided the scores into thirds to yield their *High*, *Moderate*, and *Low* ratings. In doing so, it is inevitable that some interventions will miss a cut-off by a mere point or two. For example, full motion simulators, improve safety programs and improve safety cultures were each classified as *"High Effectiveness"* but fell one point short of *Moderate Feasibility*. Following the specific recommendations of the Team, these highly effective interventions would not be pursued. Clearly, the most highly ranked interventions in both effectiveness and feasibility should be investigated very carefully for possible implementation. However, operators, manufacturers, associations, and programs should review this entire list of possible interventions to identify opportunities, such as full-motion simulators, that are within their capacity for improvement and enhanced safety.

AIR MEDICAL ACCIDENT ANALYSIS: CONSOLIDATED PROBLEM STATEMENTS

Pilot Performance Issues:

- Loss of situational awareness
- Poor aeronautical decision making
- Limited experience in make/model
- Flight check not conducted in operational type of aircraft
- Pilot disregarded company policies
- Inadequate preflight planning
- Pilot failed to obtain weather briefing
- Pilot ignored weather briefing
- Pilot not wearing helmet
- Pilot continued VFR flight into IMC conditions
- Pilot descending to avoid IMC
- Pilot fails to maintain safe altitude
- Pilot fails to conduct area recon
- Pilot fails to conduct pre-departure briefing
- Improper response to inflight emergency
- Inadequate Nr (rotor RPM) control
- Pilot failed to recognize and avoid power settling
- Improper pilot technique
- Pilot took off with sun in eyes
- Destination position not entered in navigation equipment
- Pilot failed to use aircraft searchlight to detect wires
- Pilot failed to hear or respond to ATC special VFR clearance
- Pilot's attention is diverted to inside the cockpit

Environmental Issues:

- Night VFR operations
- Night IMC operations
- Reduced visibility
- Mountain operations
- High altitude operations
- Featureless terrain

Aircraft Issues:

- Aircraft not IFR certificated
- No autopilot or second pilot
- Poor configuration of navigation equipment
- Pilot unable to determine altitude above LZ
- Pilot unable to detect weather
- Pilot unable to detect wires
- Misleading/inaccurate fuel quantity gauge
- Aircraft flotation inadequate for existing sea conditions
- Uncrashworthy fuel tank

Infrastructure Issues:

- ATC unclear regarding pilot's request
- Inadequate vector by ATC to intercept localizer
- Pilot unable to obtain ATIS (Automated Terminal Information Service) information
- Airport uncontrolled
- Airport congested, requiring landing on ramp
- Helipad small
- Helipad surrounded by obstacles
- Powerlines did not meet marking criteria
- Powerlines not depicted on aeronautical charts

Landing Zone Issues:

- Difficulty identifying landing zone
- No landing site supervisor
- Incorrect/inadequate obstacle information on LZ
- Congested landing zone
- Obstacle-rich environment

Corporate/Management Issues:

- Corporate pressure to complete the mission
- Personal pressure to complete the mission
- "Ready Aircraft" change required equipment transfer
- Preflight preparations rushed

Figure 1–25: Consolidated Problem Statements
Adopted from: Air Medical Accident Analysis, 2001

		EFFECTIVENESS		
		High	**Moderate**	**Low**
FEASIBILITY	**High**	• Enhance the training for night flying operations • Enhance the training for mountain flying operations • Equip aircraft with Terrain Avoidance Warning Systems (TAWS) • Equip aircraft with radar altimeters • Provide aircraft with mission-essential equipment • Improve the content of weather briefings	• Enhance the awareness of accident causes • Improve physiological training • Improve training with avionics equipment: usage, capabilities, etc. • Improve weather radar • Encourage greater utilization, interaction with and assistance from Air Traffic Management • Improve/enhance training of ATC personnel in rotorcraft operations and capabilities • FAA to enhance training elements of Biennial Flight Reviews and Pilot Training Standards	• Readily available crew/passenger briefing cards • Fuel flow indicators • Simplify calling FSS • Publish a mountain flying advisory circular • Publish a "flat light/whiteout" advisory circular • Require flight plans • Provide more UNICOM frequencies
	Moderate	• Conduct/enhance annual IFR proficiency checks • Conduct/enhance training to improve the understanding of weather briefings • Enhance overall training: recurrent, professional knowledge, etc. • Conduct/enhance training in ADM • Establish an integrated and structured Pilot Training Program • Conduct/enhance mission-oriented training • Conduct/enhance CRM training • Equip aircraft with Moving Map Displays to provide weather, obstacle, and terrain data • Equip aircraft with avionics to provide a vertical awareness display or warning • Standardize cockpits of similar make/model used in similar operations • FAA to enhance/improve contents of annual IFR proficiency checks • Establish national criteria for the marking of wires and towers	• Operators to enhance training for Biennial Flight Reviews and Pilot Training Standards • Develop helicopter-specific, mission-specific computer-based emergency procedures simulators • Develop satellite-based Communications, Navigation and Surveillance (C/N/S) technology • Increase the rate of commissioning of new AWOS/ASOS (Automated Weather Observing System/Automated Surface Observing System) facilities • Improve aeronautical charts (symbology, data, etc.)	• Improve pilot handbooks • Data link technology • Require annual calibration of fuel quantity gauges
	Low	• Horizontal Awareness From Terrain • Synthetic vision • Heads-up display • Night vision devices • Full-motion simulators • Enhance visibility/detection of wires and towers • Change corporate mind-set • Improve safety culture • Improve safety program	• ADS-B (Automatic Dependant Surveillance-Broadcast) Technology • Automated voice call-outs • Over-bank warnings • Excess terrain closure warnings • improve equipment with state-of-the-art technology • Prohibit night flying by non-IFR rated pilots • Require human factors/ergonomics in cockpit designs	• Increase dual-pilot time prior to solo PIC • Increase time requirements for "mission certification" • Obstacle database • Enhanced ice detection equipment • Raise minimums for night instrument approaches • Require ATC monitoring of instrument approaches • Prohibit night VFR • Update FAR Part 135 requirements • Require crashworthy fuel tanks for certification

Adapted from: Air Medical Accident Analysis, 2001

HEMS ACCIDENTS AND INCIDENTS, 1998 TO 2001

The past four years has seen an alarm- ıcrease in the number of HEMS accidents across the nation. No one is certain why there have been 43 accidents (plus one dual-purpose medical helicopter accident) in four years. From 1987–1997, dedicated HEMS has averaged 4.9 accidents per year. The past four years averaged 10.75 per year. Not since the four year period of 1983 to 1986 have we seen such a large number of accidents.

While a few of the reports that we reviewed included accidents from 1998 to 2000, none of these studies isolated these years from the rest of their accidents. Therefore, with no published review of the most recent series of accidents, we determined that it was necessary to do our own preliminary review of these accidents to see if any trends could be identified.

Several resources and databases were reviewed in the development of Attachment 1. This table presents the pertinent data on 44 HEMS accidents between 1998 and September 30, 2002.

Attachment 1 does not include any -wing EMS. In addition, we have ıncluded an accident that killed three crewmembers in England, a non-EMS helicopter that crashed on a hospital helipad, or an "as needed" service that crashed after picking up three firemen to respond to a medical emergency in Hawaii. Finally, two additional accidents were not included which involved medical helicopters that had been "out-of-service" for at least several days and were undergoing post-maintenance test flights.

Of the 44 accidents from 1998 to 2001, 15 (34%) resulted in at least one fatality. For the 1980s, our accident database showed 39% of all accidents resulted in at least one fatal injury. From 1990–1997 the rate increased to 47%. Despite the increase in accidents over the past four years, the percentage of fatal accidents has declined by nearly 30%. Figure 1–27 depicts the percentage of fatal accidents since 1980. As the figure shows, the last four years has had the lowest consecutive 4-year fatality rate in HEMS history since arly 1980s.

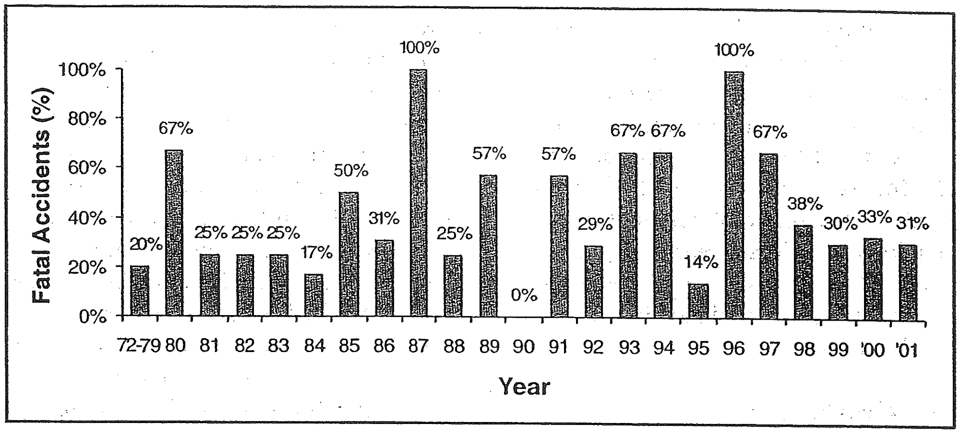


Figure 1–27: Percentage of Fatal Accidents per Year

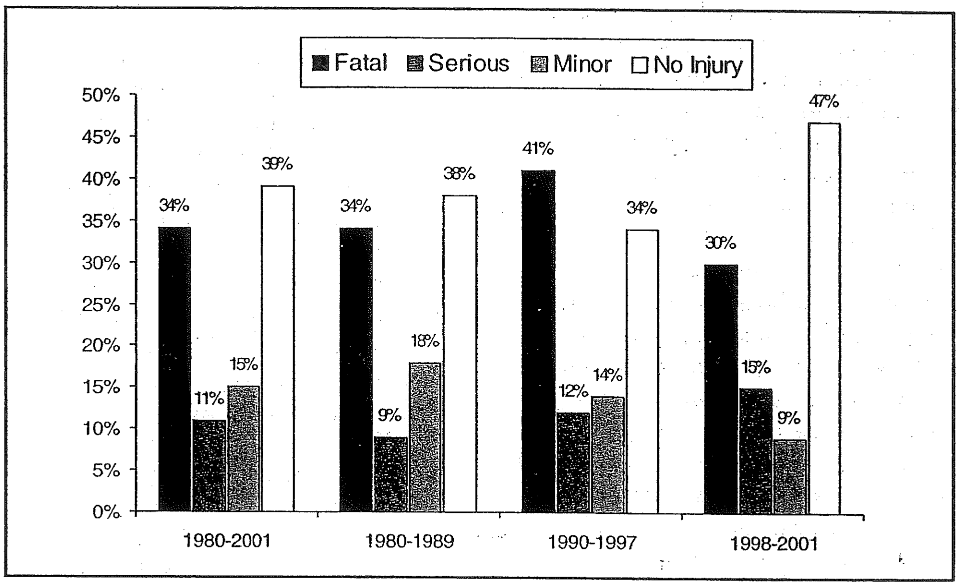


Figure 1–28: Severity of Injuries for HEMS Accidents, 1980 – 2001
(1980–2001, n=494; 1980–1989, n=247; 1990–1997, n=116; 1998–2001, n=131)

ɔking at the breakdown of all injuries (Figure 1–28), there is also a significant difference noted in the percentage of crewmembers who sustained no injuries in HEMS accidents. Figure 1–28 shows four different comparisons: the entire 21-year study period; the 1980s; 1990–1997; and finally 1998–2001. The percentage of fatal injuries has decreased in 1998–2001 and we now see 47% of the crewmembers and passengers sustained no injuries.

Since 1998, a slightly higher percentage of HEMS accidents occurred at night (52%). More accidents occur during the cruise phase of flight (16) than any other phase and we now see a similar number of accidents occur on takeoff and landing (8 each). More accidents (45%) are taking place during scene missions than previously noted (35%). Finally, our preliminary review of the HEMS accidents seems to show a decrease in the percentage of weather-related accidents. Frazer had noted an increase in weather-related accidents from 22% in the '80s to 32% in the early and mid-'90s. From 1998 to 2001, there appear to be 6 weather-related accidents, dropping the percentage to 14%.

HEMS ACCIDENT AND FATAL ACCIDENT RATES

The UCAN Safety Committee felt that an important aspect of our research would be to determine HEMS accident and fatal accident rates for our entire study period (1980–2001). In order to normalize the raw accident data for a meaningful comparison of dedicated HEMS accidents, it is necessary to have two key elements—the number of accidents (total and fatal) and the number of flight hours flown or the number of patients transported for the entire industry each year. We have already reviewed the accident data that is readily available from several sources. Unfortunately, as previously mentioned, a major obstacle is our lack of accurate HEMS exposure data (e.g., flight hours, patients transported) making it impossible for a meaningful year-to-year comparison. Dual-purpose medical helicopter accidents are not included in this portion of the report.

Methodology

Our research model required that an extensive review of the air medical literature be conducted to determine what data was available that could be used to normalize the HEMS information. We found that in 1982, *Hospital Aviation* began to track and publish statistics and accident rates that were based on the number of patient transports (rather than flight hours) for the air medical industry. In 1988, *Hospital Aviation* also looked at revenue flight hours as well as patient transports. Their survey found that the average patient transport corresponded to 1.05 revenue flight hours. Because of this finding, accident rates continued to be tracked based upon patient transports. No data were collected on total hours flown (training, repositioning, maintenance, PRs, etc.). In the journals, the "per 100,000 patients transported" accident rates were found through 1992 and resurfaced again in a 1997 article that provided a graph for the years 1978 through 1995.

"Annual Transport Statistics," the results of another industry-wide survey, was published first in *Hospital Aviation*, and then in the *Journal of Air Medical Transport*, the *Air Medical Journal*; and then in *AirMed*. This analysis provides information on *averages* per flight program (as well as highs and lows) for the year, region-by-region, and across the United States. This included information on the average number of patients transported, interfacility missions, scene missions, night flights, and loaded miles. In 1994, they also started to include average flight hours in the survey results. Personal correspondence with Bill Rau, who had authored the transport survey articles since 1996, stated that the survey asked for "total annual flight hours excluding PR flights."

A final source of HEMS statistics was the "Mid-Year Report" that identified (among other related data) the number of hospital-based programs and helicopters. This data was found from 1984 through 1989 in *Hospital Aviation* and subsequently in the *Journal of Air Medical Transport*. Several additional articles and the 1988 NTSB report were also reviewed to provide raw data.

Total flight hours and total patient transports were unavailable for more than 50% of the years reviewed. From the "Annual Transport Statistics" we did have the average number of patients transported per program per year and the average flight hours per program. Unfortunately, we lacked any estimate as to the number of HEMS programs in operation since 1992. In order to normalize the HEMS data, the missing information would need to be obtained or estimated.

In an effort to estimate the number of HEMS programs, several assumptions were made. If we could determine the number of programs and helicopters currently in operation (November/December 2000), we could estimate the total flight hours and patients transported during the year. In addition, unlike the early 1980s, we assume that the growth in the industry has been fairly constant over the past eight years. We would then be able to estimate the number of programs and helicopters for the years lacking data.

To determine a fairly accurate number of dedicated HEMS programs and helicopters, we undertook a review of the Association of Air Medical Services (AAMS) Membership Directory and the Directory of Air Medical Programs, published in the May/June issue of *AirMed*. Unfortunately, neither resource is complete. Not all air medical programs are AAMS members and neither directory includes the total number of aircraft. To supplement this data, a survey was posted on the Internet's *Flightweb* listserve. The survey requested state-by-state information on the number of dedicated HEMS programs (hospital-based, independent, etc.) and the number of dedicated helicopters.

Knowing the flight hours is the next consideration in an attempt to normalize the HEMS data. The NTSB document reported flight hours for 1980 through 1985, but did not specify if their figures correspond to revenue flight hours or total flight hours. In addition, the *AirMed* surveys provide average flight hours per program from 1993 to 2000. If we are successful in estimating the total number of HEMS programs in operation from 1993 to 2000, we will be able to estimate the total flight hours.

Total flight hours is an important consideration in our evaluation. In HEMS, a considerable number of accidents occurred on non-patient missions—including PRs, refueling, maintenance, training, and so on. The average flight hours per program, as published in the *AirMed* surveys, should have included all flight hours except PRs. The vast majority of HEMS flight hours are patient missions. Personal correspondence with several HEMS programs and operators suggests that non-patient flight time may range from 5 to 15%. PR flights made up approximately half of this for many programs.

In an effort to more accurately determine the average number of *total* flight hours per program, a survey of five of th largest HEMS operators was conducted. These operators were chosen with the knowledge that they account for the majority of the air medical programs in the country. The operators were asked for total flight time, total number of programs and total number of helicopters they operated for the years 1998 through 2000. The goal was to compare these flight hours with the information published in *AirMed* for 1998 and 1999. In addition, a correlation could then be made comparing revenue flight hours and total flight hours for other years.

Results

In review of the available published statistics, several limitations and problems were identified that make accurate yearly comparisons very difficult. Most important, the "Annual Transport Statistics" report only on hospital-based HEMS programs. Over the years, more and more HEMS operations have deviated from this original, yet still dominant model. In 1989, the journals began sending surveys to non-hospital helicopter programs, but the data was never included in the published average statistics. In 1989, the total number of patients trans-ted by these non-hospital programs referenced. However, these numbers included some dual-purpose helicopter programs as well.

Another problem was timing of the data collected. Some statistics regarding the number of helicopter programs and total number of helicopters were published in *Hospital Aviation* in a mid-year (July) report, while other program and helicopter statistics were based on the calendar year. The *Annual Transport Survey* was based on the calendar year until 1993 when it was switched to the academic (July to June) year for annual statistics tabulation. In general, annual accident statistics were based on the calendar year.

Since 1986 the journal surveys were sent to both helicopter and fixed-wing programs. The percentage of surveys returned ranged from a high of 96% to a low of 33%. In general, the yearly data was fairly consistent. The one exception was 1994, which had significantly *higher* average flight hours per program and much *lower* loaded miles than other years.

The results of the literature search and the following calculations can be found in Figure 1–29. The data obtained from the various publications is presented in ***bold italics*** while the calculations and surveyed data is in plain type.

Helicopter EMS Programs and Helicopters. Data was available for the number of HEMS programs from 1972 to

Figure 1–29: HEMS Program, Helicopter and Accident Statistics (Published data is in bold italics)

1	*Data for Year*	*72–79*	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*
2	Year Data was Published					[1984]	[1985]	[1986]	[1987]	[1988]	[1989]
3	Avg Pts Flown / Program		546	676	654	***553***	***570***	***590***	***623***	***698***	***697***
4	Avg Loaded Miles					***61***	***63***	***61***	***61***	***61***	***58***
5	Avg Hrs Flown / Program	See total hours below (Line 8a)							654	733	732
6	Avg Flt Hr / Pt Transport								1.05	1.05	***1.05***
7	Avg Total Hrs/Prog								710	795	794
8a	Total Flight Hrs (-PR)		***20,750***	***28,071***	***36,794***	***45,233***	***56,516***	***71,831***	84,385	106,271	113,437
8b	Total Flight Hrs		***20,750***	***28,071***	***36,794***	***45,233***	***56,516***	***71,831***	91,558	115,303	123,079
9	# of Programs		32	***37***	***49***	***62***	***76***	***101***	***129***	***145***	***155***
	# of Helicopters		39	***45***	***62***	***75***	***91***	***119***	***151***	***184***	***195***
11	Total Pts Flown	***30,168***	***17,483***	***25,013***	***32,027***	***41,097***	***51,855***	***68,694***	***87,299***	***105,000***	***120,900***

14	Year	72–79	1980	1981	1982	1983	1984	1985	1986	1987	1988
15	HEMS Accidents	5	3	4	8	8	6	12	13	4	8
16	Dual-Purp. Acc.										
17a	Accident Rate (TFH)		14.46	14.25	21.74	17.69	10.62	16.71	14.20	3.47	6.50
17b	Accident Rate (-PR)		14.46	14.25	21.74	17.69	10.62	16.71	15.41	3.76	7.05
17c	Difference		0.00	0.00	0.00	0.00	0.00	0.00	1.21	0.29	0.55

18a	% programs w/ accidents		9.4%	10.8%	16.3%	12.9%	7.9%	11.9%	10.1%	2.8%	5.2%
18b	% helicopters w/ acc.		7.7%	8.9%	12.9%	10.7%	6.6%	10.1%	8.6%	2.2%	4.1%

19	Fatal Accidents.	1	2	1	2	2	1	6	4	4	2
20	Fatal Dual-Purp.										
21	Fatal Acc Rate		9.64	3.56	5.44	4.42	1.77	8.35	4.74	3.76	1.76
22	% Fatal Acc.	0.20	0.67	0.25	0.25	0.25	0.17	0.50	0.31	1.00	0.25
23	per 100,000 pts	16.57	17.16	15.99	24.98	19.47	11.57	17.47	14.89	3.81	6.62

Key to Lines:

Survey results are routinely published in the following year.

3–99, published data. 80–82, calculated (total pts flown / # of programs)

83–99, published data.

5. *93–99, published data. 86–92, calculated (ave # pts transported per program X 1.05).*
6. *88, published data. 93–99, calculated (ave hrs per program / ave pts flown per program)*
7. *98–2000, operator survey. 86–97, calculated (line 5 X 1.085)*

1992 (Figure 1–29, Line 9) and information on the total number of helicopters was available for 1981 to 1991 (Figure 1–29, Line 10). From the *Flightweb* survey and personal follow-up, information was obtained from 45 of the 50 states (plus the District of Columbia). Program data for the remaining states was estimated from the *AirMed* directory. The survey results identified 231 dedicated HEMS programs, operating a total of 377 helicopters (not including back-up aircraft).

Additional follow up with several industry leaders and aircraft manufacturers suggests that, if anything, these numbers may be slightly underestimated. From a telephone survey of the five aircraft manufacturers, it was estimated that there were a total of 462 dedicated and backup medical helicopters in the United States. This did not include dual-purpose helicopters. From the operators' survey, there was an average of one backup helicopter for every 7.1 dedicated helicopter in their combined fleets. Using this ratio, it would appear that our state-by-state survey of 377 helicopters would have an estimated 53 backup aircraft yielding a total of 430 helicopters. This represents a variation of approximately 7% fewer aircraft compared to the number of helicopters from the manufacturers' survey. This may also indicate a slight discrepancy in the number of HEMS programs resulting from our Internet survey. In using the lower state-by-state survey results of 377 dedicated helicopters and 231 programs for our calculations, we realize that we may be underestimating our flight hours and number of patients transported. This also results in higher accident and fatality rates.

1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
[1990]	[1991]	[1992]	[1993]	[1994]	[1995]	[1996]	[1997]	[1998]	[1999]	[2000]	N/A	N/A
705	**709**	**869**	**876**	**805**	**812**	**813**	**845**	**827**	**796**	**880**	832	882
60	**58**	**57**	**55**	**49**	33	**47**	**47**	**47**	55	58	**50.76**	51
740	744	912	920	**876**	**1159**	**785**	**823**	**823**	**814**	**821**	813.22	911
1.05	1.05	1.05	1.05	1.09	1.43	0.97	0.97	1.00	1.02	0.93	0.98	
803	808	990	998	950	1258	852	893	893	**854**	**921**	**841**	**957**
122,141	129,534	162,416	169,141	166,245	226,778	158,221	170,727	175,573	178,447	184,839	187,854	210,396
132,523	140,545	176,221	183,518	180,376	246,054	171,670	185,239	190,497	187,216	207,327	194,271	217,584
165	**174**	**178**	**184**	190	196	202	207	213	219	225	231	231
213	**231**	**225**	242	259	276	293	309	326	343	360	377	400
125,200	**159,027**	154,682	161,087	152,771	158,881	163,865	175,291	176,427	174,501	198,098	192238	203,772

1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
7	1	7	7	3	6	7	1	3	8	10	12	13
2		1							1			
5.28	0.71	3.97	3.81	1.66	2.44	4.08	0.54	1.57	4.27	4.82	6.18	5.97
5.73	0.77	4.31	4.14	1.80	2.65	4.42	0.59	1.71	4.48	5.41	6.39	6.18
0.45	0.06	0.34	0.32	0.14	0.21	0.35	0.05	0.13	0.21	0.59	0.21	0.20

4.2%	0.6%	3.9%	3.8%	1.6%	3.1%	3.5%	0.5%	1.4%	3.6%	4.4%	5.2%	5.6%
3.3%	0.4%	3.1%	2.9%	1.2%	2.2%	2.4%	0.3%	0.9%	2.3%	2.8%	3.2%	3.3%

4	0	4	2	2	4	1	1	2	3	3	4	4
1		1							1			
3.27	0.00	2.46	1.18	1.20	1.76	0.63	0.59	1.14	1.68	1.62	2.13	1.90
0.57	0.00	0.57	0.29	0.67	0.67	0.14	1.00	0.67	0.38	0.30	0.33	0.31
5.59	0.63	4.53	4.35	1.96	3.78	4.27	0.57	1.70	4.58	5.05	6.24	6.38

8a. 72–85, published data. 86–92, 93–99 calculated (# of program X Avg flight hrs per program).

8b. 72–85, published data. 86–2000, calculated (line 7 X line 9)

9. 72–92, published data. 2000, Flightweb survey. 93–99, calculated assuming consistent growth for 92–00

10. 81–91, published data. 2000, Flightweb survey. 92–99, calculated assuming consistent growth for 91–00.

11. 80–90, published data. 91–99 calculated (# of programs X Avg # of pts transported each year).

17a. 80–99, calculated. (100000 X number of accidents)/total flight hours for the year

17b. 80–99, calculated. (100000 X number of accidents)/total flight hours for the year, excluding PR

Our *Flightweb* survey results were entered into an Excel spreadsheet for the year 2000 along with the published data rough 1991/1992. The estimated num- of programs and helicopters for 1992/1993 through 1999 were then calculated assuming a consistent growth rate each year. The results are found in Figure 1–29, Lines 9 and 10.

Flight Hours. Total flight hours for the HEMS industry were available for 1972 to 1985 (Figure 1–29, Line 8a and 8b). In addition, the average total flight hours per program, excluding PR flight time, were published for 1983 to 1999 (Figure 1–29, Line 5). Total flight hours (less PR flights) for 1993 to 1999 could now be estimated (number of programs X average flight hours per program).

For 1986 to 1992, we had to first estimate the average number of flight hours per program. We relied upon Collett's previously documented average of 1.05 flight hours per patient flight in 1988 when the average loaded flight was 58 miles. To test this hypothesis, we calculated the average flight hours per patient transport from 1993 to 1999 (Figure 9, Line 6). Over these seven years, e average was 1.058 flight hours per patient transport—despite the fact that the loaded miles had decreased. Multiplying 1.05 times the average number of patients transported per program per year for 1986 to 1992, we were able to estimate the flight hours needed to normalize our data.

To determine the accuracy of the calculated total flight hours, we compared *AirMed's* average flight hours per program to the results of our HEMS operator survey. For the year 2000, the companies operated 160 programs and 269 dedicated helicopters. Comparing this to our *Flightweb* survey results (231 programs and 377 helicopters), the operators represent 69% of the HEMS programs and 71% of the helicopters. In 1999, the average total flight hours per program was 925 hours for our five operators. This represents a 12% increase over the 821 hours published in *AirMed*. Based upon our operators' survey, the 1998 erage was 854 hours. This corresponds 5% increase compared to the *AirMed* survey for that same year. Taking into account our earlier estimates regarding non-patient flight time and PR flight time, these calculated increases (an average of 8.5%) seem accurate. Figure 1–29, Line 7 lists the average *total* flight hours per program from our operators survey results (1998 to 2000) and the calculated values for 1986 to 1997. This is done by multiplying the previously recorded average flight hours per program (Figure 1–29, Line 5) by 1.085. Total flight hours for each year can now be more accurately estimated, as documented in Figure 1–29, Line 8b.

Patients Transported. The journals published data on the total number of patients transported each year from 1980 to 1990. With the number of programs now estimated for each year, the total number of patients transported annually from 1991 through 1999 could also be estimated (number of programs X the average number of patients transported each year).

Accident Data. The yearly accident and fatal accident data (Figure 1–29, Lines 15 and 19) were obtained and summarized from several resources. The references included the NTSB and NASA websites, the CONCERN Network, and personal databases from several industry leaders.

Year 2000. For the year 2000, *AirMed* no longer published their "Annual Transport Statistics," which included the average number of patients transported and hours flown. In order to estimate these numbers, the *AirMed* survey results for the previous five years were averaged. It is interesting to note that our operators' survey shows a decrease in the average flight hours per program to 841 hours, a decrease of 9% compared to 1999 figures.

Year 2001. In order to include the 2001 HEMS accidents in our calculations, additional information was obtained from our aviation operators and aircraft manufacturers. Recognizing that the operators represented approximately two-thirds of the programs and helicopters in our earlier analysis, this seemed an appropriate perspective for year 2001 projections.

Operators were asked for their 2001 total flight time, total number of programs, and total number of helicopters operated. The combined results identified 159 programs and 286 dedicated helicopters. Compared to 2000, this was a decrease of one HEMS program, while 17 additional helicopters were placed in service—an increase of 6%. Follow up with the aircraft manufacturers, however, showed a one-year increase of 13% for the total number of EMS helicopters. Combined total flight hours according to the operators increased at the same rate, showing a gain of 13% over the previous year. These values were used to calculate 2001 data for our comparisons.

Accident Rates

The necessary data is now available to normalize the HEMS data and compare what has occurred each year. Accident rates were calculated using all of the accidents that were included in Figure 1–29. This included patient and non-patient missions. The only medical helicopter accidents excluded were several dual-purpose helicopter accidents, two maintenance flights where the aircraft were not in service to the HEMS program at the time of the accident, and a training flight of a newly hired pilot preparing for his check ride.

The first comparison for the HEMS accidents is a determination of the accident rates per 100,000 flight hours (Figure 1–29, Line 17a). The formula ([100,000 X number of accidents]/total flight hours for the year) used the total flight hours as calculated with the 8.5% increase (Line 8b) to account for all flight time (patient and non-patient missions). A second accident rates per 100,000 flight hours was calculated (Figure 1–29, Line 17b) using the total flight hours before the increase. The difference between these two accident rates for each year ranged from 0.05 to 1.3 accidents per 100,000 flight hours with an average difference of 0.39 accidents per 100,000 hours. When these two accident rates were graphed together, they virtually overlapped. As a result, we are only including the calculations from Line 17b in our graphic analysis, which depicts the slightly higher rate.

Figure 1–30 shows that there has been a dramatic decrease in the accident rate since the mid-'80s. As the raw data would predict, the accident rate since 1998 has steadily increased. However, despite this increase, the rate remains oughly one-third of what we experinced in the early to mid-1980s due to the overall increase in flight hours.

Looking at an average accident rate for the past 10 years 1992–2001 (3.53 accidents per 100,000 flight hours), the average HEMS program flying 911 hours per year, would have one accident over 31.1 years of flight time. Changing this calculation to include the accident rates for the past 5 years, (1997–2001), we see a moderate change. We now have a 5-year average of 4.56 accidents per 100,000 flight hours and the prediction for the average program decreases to one accident over 24.1 years. Naturally, if a program flies less, the number of years would go up, and if a program flies more, the time frame would decrease. Another way to propose the likelihood of an accident would be to compare the number of accidents to the number of programs (or helicopters). Again, using the most recent ten years, there has been an average of 7 accidents each year. With 231 dedicated HEMS programs, and assumng all things being equal, we would find a similar prediction of one accident per program every 33 years. If you base this comparison on the number of dedicated helicopters estimated for 2001 (400) rather than programs, the margin now goes up to nearly 57.1 years. Looking at the average number of HEMS accidents (9) for the past five years, we would expect one accident per helicopter every 44.4 years.

The second comparison is looking at the fatal accident rate per 100,000 flight hours (Figure 1–29, Line 21). Here too, in Figure 1–31, we see a dramatic improvement since the early and mid-1980s. Our current rate, despite having gone up slightly over the past few years, is approximately 75% less than our worst years. Once again if we take an average flight program and an average fatal accident rate for the past ten years (1.38 fatal accidents per 100,000 flight hours), we would predict one fatal accident while flying more than 79.3 years. When we focus on the average fatal accident rate for 1997–2001 (1.69) this figure drops to 64.8 years. The final normalized comparison will look at the HEMS data in much the same manner as was done in the '80s—comparing the accident rate per 100,000 patients transported (Figure 1–29, Line 23). With a high correlation of flight time per patient transport, Figure 1–32 is very similar to the Figure 1–30.

We would expect similar results if we again look at our average flight program. With a 10-year (1992–2001) average accident rate of 3.89 accidents per 100,000 patients transported and the typical HEMS program flying 882 patients in a year, a program would have one accident while transporting an estimated 25,700 patients over 29.2 years. Calculations for 1997–2001 (4.79 accidents per 100,000 patient transports) resulted in an estimate of one accident while transporting nearly 21,000 patients over a 23.74 year period.

It may be of interest to note a 1990 study by Rhee et al., that compared the HEMS accident rate in the United States to that of the Federal Republic of Germany. For 1982–1987, Rhee's calculations found an accident rate in the U.S. of 11.7 per 100,000 flight hours. The calculated accident rate for West Germany was found to be comparable at 10.9 per 100,000 flight hours. The fatal accident rates were also found to be similar. The U.S. rate was 4.7 fatal accident per 100,000 flight hours while the West German rate was 4.1. In contrast, using our own database and calculations for

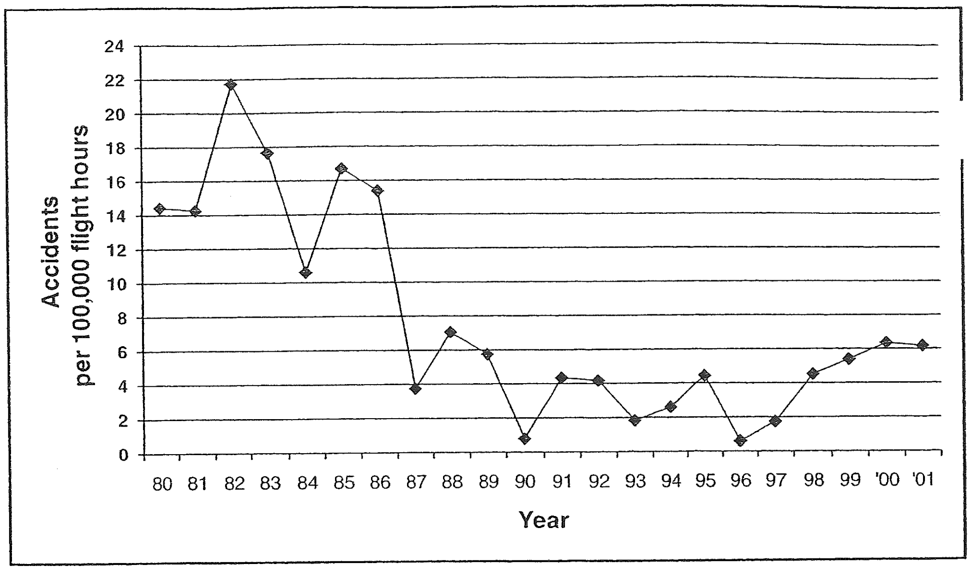


Figure 1–30: Accident Rates for HEMS Operations, 1972 – 2001

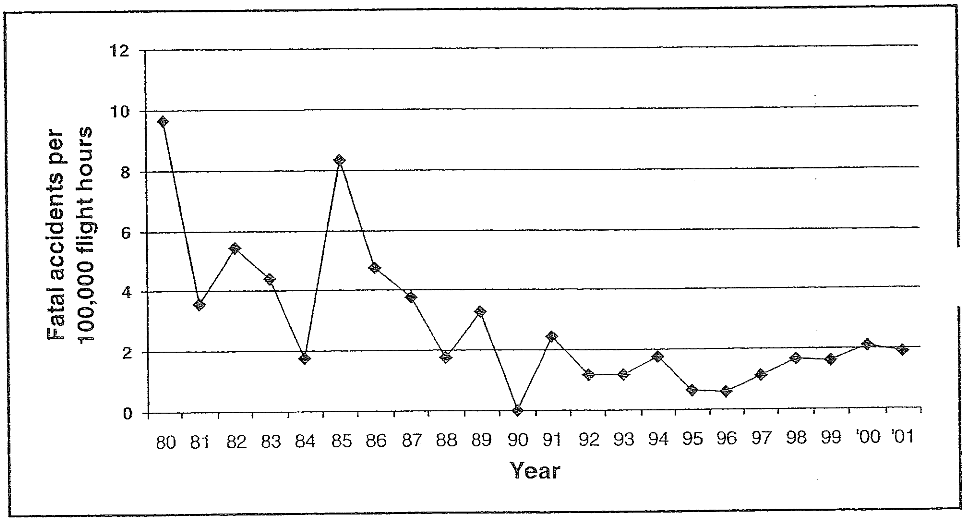


Figure 1–31: Fatal Accident Rates for HEMS Operations, 1972 – 2001

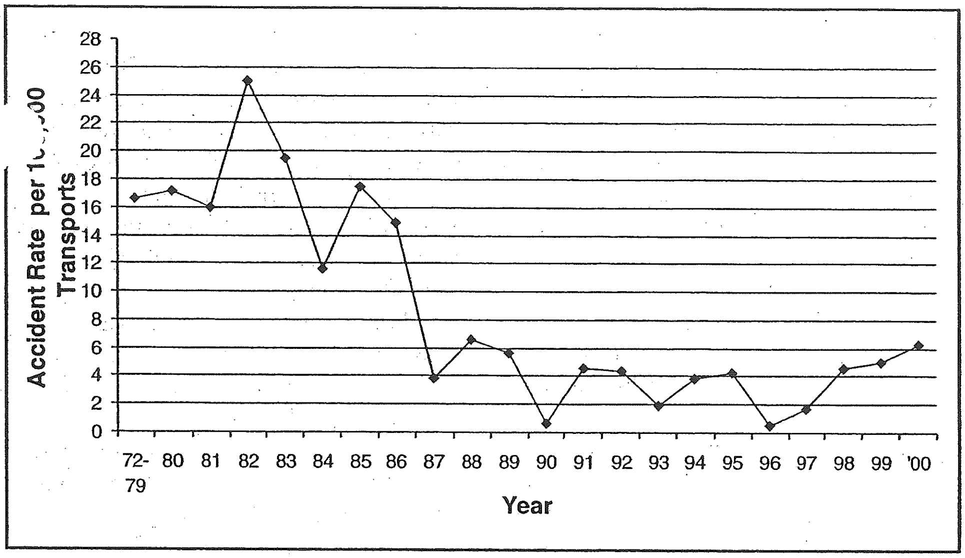


Figure 1–32: HEMS Accident Rate per 100,000 Patient Transports, 1972–2000

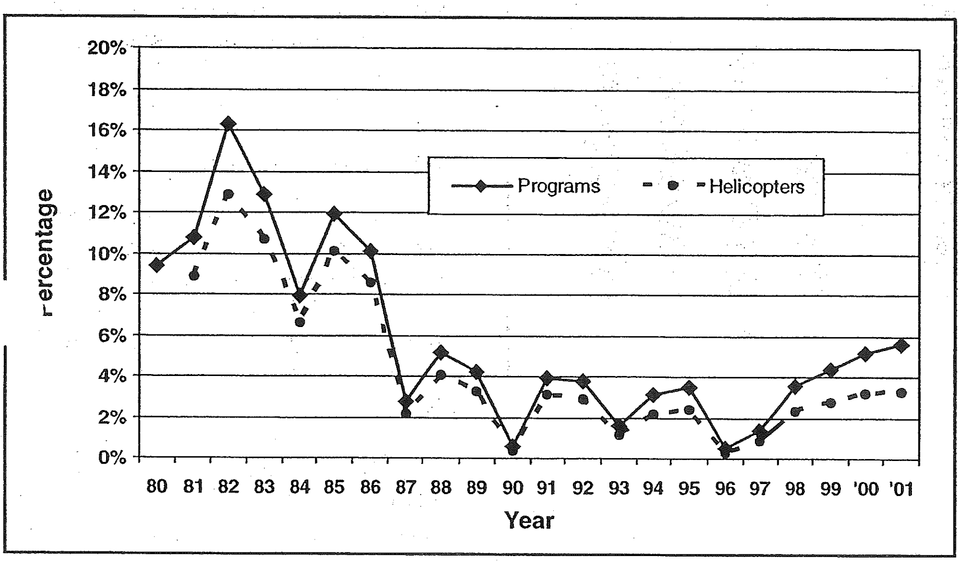


Figure 1–33: Programs and Helicopters with Accidents, 1980–2001

this same time frame (1982–1987), our statistics yield a much higher accident rate of 15.58 per 100,000 flight hours and a fatal accident rate of 5.2.

Percentage of HEMS Programs and Helicopters Involved in Accidents

Data is not available to accurately determine what percentage of HEMS programs have sustained an accident. Over nearly 30 years of civilian HEMS operations, dozens of programs have closed and ers have merged operations. However, with the data that we have accumulated to estimate the number of programs and helicopters each year, we can determine annual percentages with some accuracy. Averaging these annual calculations, we can estimate the overall percentage of HEMS programs and helicopters that have had accidents. These calculations do not take into account the possibility that an individual program may have suffered more than one accident—which has occurred.

The calculated percentage of programs and helicopters that sustained accidents each year since 1980 is shown in Figure 1–29, Lines 18a and 18b. The five accidents that occurred prior to 1980 are not included, as we do not have annual statistics on the number of programs or helicopters before 1980. Figure 1–33 shows the wide range for our results. In 1982, an estimated 16.3% of the HEMS programs (8 accidents, 49 programs) were involved in accidents. The safest year was in 1996, when an estimated 0.5 % of the programs had an accident (1 accident, 207 programs). Overall, the average annual percentage over 22 years calculates to 5.8% of the programs having had accidents between 1980 through 2001. If you consider only the past five years, an average of 4.1% of the programs have had an accident each year.

Calculating the percentage of helicopters that were involved in HEMS accidents each year finds a high of 12.9% of the HEMS aircraft in 1982 (8 accidents, 62 helicopters). In 1996, there was 1 HEMS accident during a year when an estimated 309 dedicated medical helicopters were in operation, for a total of 0.3%. The average percentage over 21 years calculates to 4.4% of the HEMS fleet. Over the past 5 years, this percentage has averaged 2.5% for each year.

SECTION 2: A COMPARISON OF HEMS TO OTHER TYPES OF AVIATION

Having reviewed HEMS-specific data, this report will now compare HEMS accident and incident data to other types of aviation. This section first looks at two reports and then focuses on various aviation industry statistics. Finally, the accident rates for helicopter air medical transport is compared to other aviation operations.

HELICOPTER EMS vs. ALL HELICOPTER ACCIDENT DATA: 1990–2000

During the 2000 Air Medical Transport Conference (AMTC), Sandra Hart of the NASA-Ames Research Center presented a study that compared characteristics of helicopter EMS accidents with those of all helicopter accidents (EMS and non-EMS) over the same time period. In March 2001, Hart presented an updated report at the Proceeding of the 11th International Symposium on Aviation Psychology.

In her introduction at AMTC, Hart pointed out that in recent years, the number of HEMS accidents has increased. However, she emphasized that all we have is raw numbers. Accurate exposure data is lacking regarding the number of transports and the number of hours flown by helicopter EMS. Without this, we do not have accurate information to determine if the increase in accidents is related to an increase in the hours flown or whether HEMS had gotten less safe. As a result, the data presented in her lecture was based upon raw numbers and percentages rather than as accident rates.

In addition, Hart stated that "aircraft accidents are poor indicators of safety trends due to a low occurrence rate and limited information about what happened. Quite often, the immediate 'cause' may have little relationship to the underlying causes. But as risk factors begin to accumulate, something bad was bound to happen."

An analysis of 1,494 helicopter accidents over a 10-year period beginning in 1990 was conducted by the NASA-Ames Research Center. The database was obtained by reviewing the NTSB accident and incident reports, looking at narratives, probable cause, occurrences, find ings and coded data (e.g., pilot experience, helicopter make/model, visibility, mission). A total of 58 HEMS accidents were identified within this database—both Part 135 (patient-related transports) and Part 91 flights (repositioning, maintenance, etc.). Of interest, 72% of the HEMS accidents were flown under Part 91 and only 30% were on patient-related missions. Some HEMS operations conduct the flight to the patient under Part 91 regulations, while other programs consider all legs of a patient flight to be Part 135.

Figure 2–1 illustrates the number of accidents that were included for each year in the Ames report. Several 1999 and 2000 accidents lacked NTSB final reports and were not included.

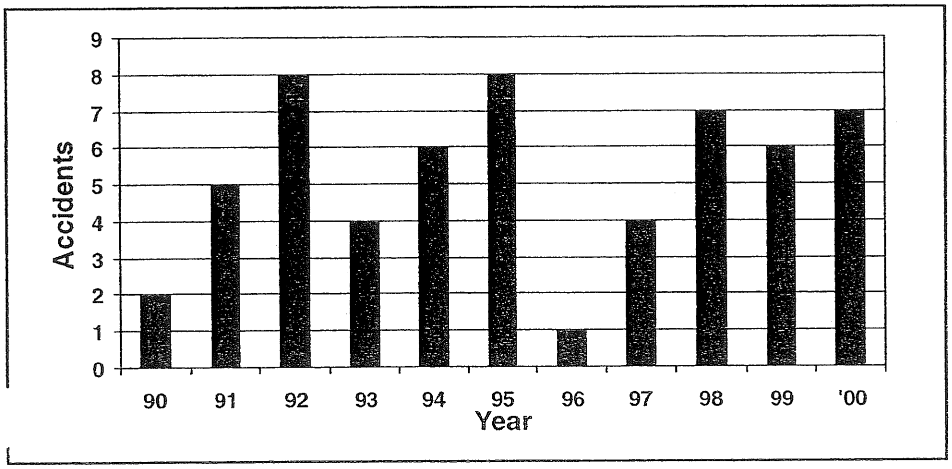


Figure 2–1: Number of HEMS Accidents per Year

Adapted from: Hart, Conference presentations, 2000/2001

When the Accidents Occur

When comparing the data, approximately 53% of the HEMS accidents occurred between dusk and dawn while only 9% of all helicopter accidents occurred at night. It is estimated that only 5% of all helicopter flights are at night.

Hart found that nearly five times as many HEMS accidents occurred in IMC conditions (24% compared to 5% for all helicopter accidents), with nearly all of them involving inadvertent flight into IMC conditions. This was consistent with the previous NTSB study. Neither snow nor rain was an identified problem, with very few helicopter accidents occurring with visible precipitation. This could be due to the fact that fewer helicopter flights occur during these types of weather conditions. Another possibility could be that pilots are more careful when they can see visible precipitation (rain or snow). In contrast, deteriorating weather conditions (decreasing ceilings or fog developing) may be less obvious.

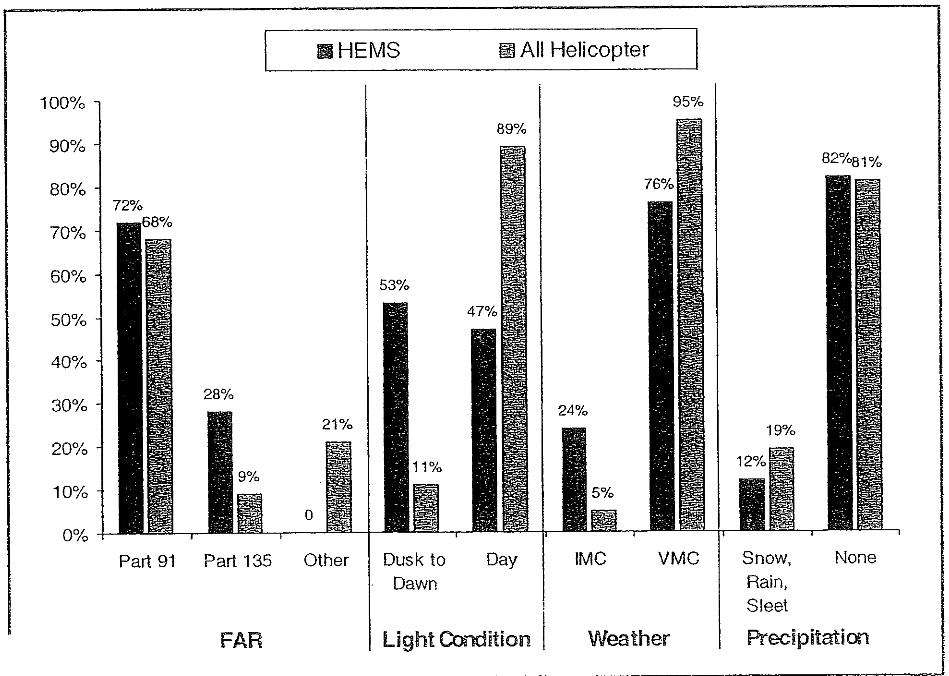


Figure 2-2: When Accidents Occur (HEMS: n=58; All Helicopters: n=1,494)

Adapted from: Hart, Conference presentations, 2000/2001

Of the 58 accidents, weather conditions were cited as a contributing factor 29 times. It is important to note that these were *factors* and not the cause of the accidents. In some cases there was more than one weather factor cited with regard to an accident or incident. Weather is therefore likely to add to the risk of a flight. It may not cause the accident, but it may increase the likelihood that an accident could occur. Weather was cited only twice as the *cause of* an accident.

With regard to the phase of flight, there are some significant differences when comparing HEMS to all helicopter accidents. For all helicopter accidents the highest percentage of accidents were seen during landing (25%), maneuvering (21%), cruise (15%), hovering (11%), and takeoff (11%). This is significantly different from HEMS accidents that occurred most commonly during cruise (24%), takeoff (19%), approach (16%), and landing (14%). Figure 2–3 shows the distribution of accidents during the various phases of flight.

Pilot Experience

Experience of the pilots was carefully reviewed by the Ames study. In general the HEMS pilots averaged slightly fewer total hours than the total pilot database (6,307 vs. 6,424). However 79% of the HEMS pilots' hours (5,010) were in helicopters. The overall group included commercial fixed-wing pilots who did much less time in helicopter aviation (66% or 4,230 hours). HEMS pilots averaged fewer hours (753) in the make/model helicopter they were flying at the time of the accident compared to pilots for all of the helicopter accidents (1,273). In addition, unlike the NTSB report, pilot fatigue was not found to be a significant factor in these HEMS accidents. According to the study, the average HEMS pilot had flown only 1.88 hours in the 24 hours prior to their accident which was less than the average (3.00) for the "all helicopter accident" group.

The Ames researchers found a significant difference with regard to instrument ratings. EMS pilots were far more likely to have an instrument rating than all helicopter pilots involved in accidents. They may not have been current and they may not have been flying helicopters that were IFR equipped, but their training and experience was noted. According to Hart, while this additional training and experience should be considered an advantage to the EMS helicopter pilots, it may have worked as a disadvantage if the pilots felt that their training and experience would allow them to "push the envelope a little bit more."

Vehicle Characteristics

There were more HEMS accidents involving twin-engine helicopters than single-engine helicopters (63% vs. 36%, respectively). This is in contrast to all the accidents where the majority of the aircraft were single-engine aircraft (89%). It is important to note that no mention or comparison is made with regard to the percentage of single- vs. twin-engine helicopters in operation—only the comparison of those involved in accidents.

Accident Characteristics

HEMS accidents have a much higher likelihood of resulting in serious injuries or fatalities than other helicopter accidents. Of the 58 accidents studied, 38% resulted in at least one fatality compared to 17% for the overall database. These results are similar to the previous studies. While there tended to be very few post-crash fires in either group, aircraft in both groups were either destroyed or seriously damaged at very high rates (92% for HEMS vs. 97% for all accidents). HEMS aircraft, however, were destroyed at a much higher rate. Figure 2–5 shows the accident characteristics for both groups.

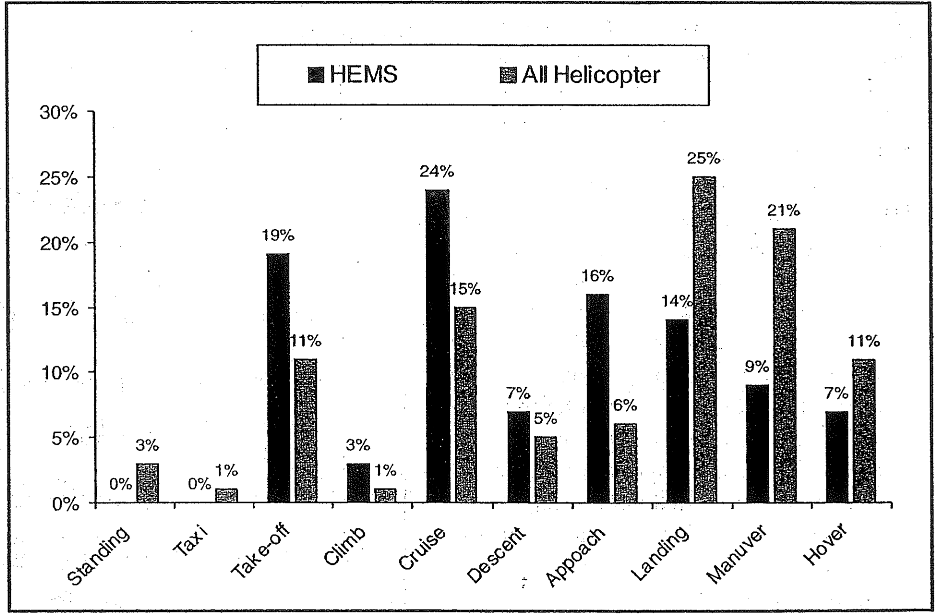


Figure 2–3: Phase of Flight (HEMS: n=58; All Helicopters: n=1,494

Adapted from: Hart, Conference presentations, 2000/2001

	EMS		All Helicopter	
	Average	Range	Average	Range
Total Hours	6,307	3,000–19,275	6,424	29–34,886
Helicopter Hours	5,010	27–17,380	4,230	8–25,000
Hours in Make	753	16–3,620	1,273	3–8,918
Instrument Hours	269	0–1,647	203	0–3,613
Prior 24 hours	1.47	0–6	3.00	0–15

Figure 2–4: Pilot Experience

Adapted from: Hart, Conference presentations, 2000/2001

Chain of Events and First Events

Hart's report emphasized that accidents e not caused by a single event. In most accidents, numerous risk factors can be identified. An accident might have an obvious identifiable cause, but there are likely to have been numerous risk factors that contributed to the event or the severity of the event. Acting on any of these risks might prevent an accident from happening or lessen the severity of the accident.

When the NTSB looks at accident data, they pay particular interest to the "first events"—the first obvious and measurable event that can be considered an accident. It is not the first occurrence in the chain of events that leads to the accident. Rather, it corresponds to the first event that would be considered evidence that an accident has taken place. First events are not causes. Their analysis tells us *what* has happened, but do not tell you *why* it happened.

The most common first event in HEMS was an in-flight collision with terrain, with wires being the primary offender. EMS helicopters were more than twice as likely to strike an object or terrain and nearly five times more likely to have an encounter with inclement weather. Relatively few of the HEMS accidents were caused by low engine power, airframe, or component failures compared to the all helicopter accident group. Hart concluded that this seems to suggest that, in general, EMS helicopters are well maintained.

The Ames study presented a cascading chain of events of what happens when an accident occurs. An in-flight encounter with weather is rarely the cause of an accident but is often the first event. It leads to an in-flight collision with an object or terrain or to a loss of engine power. Another frequent first or second event is loss of control in flight, which may follow some type of system failure (which is rare).

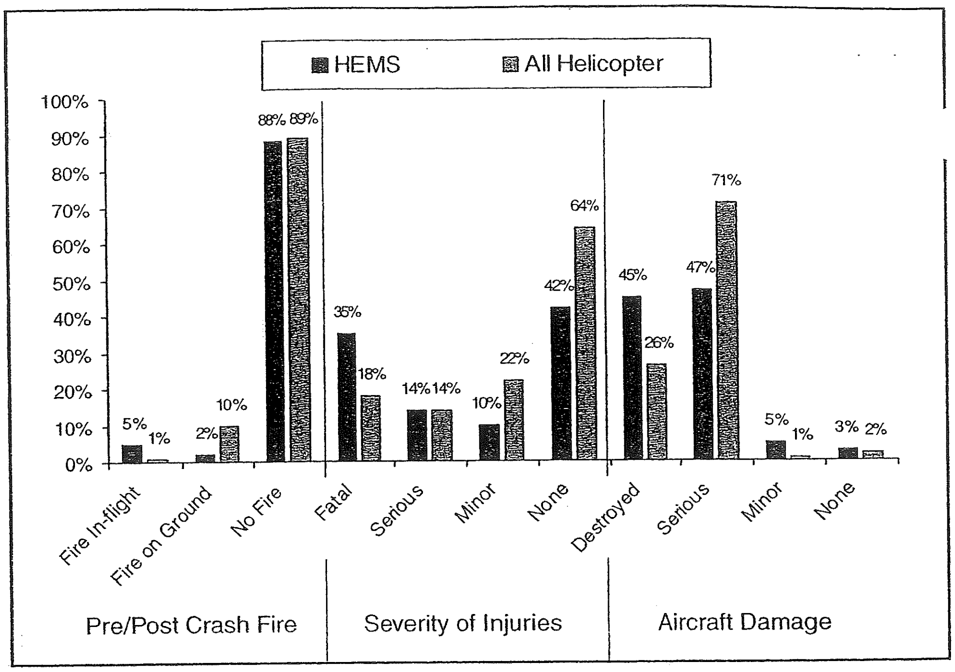


Figure 2–5: Accident Characteristics (HEMS: n=58; All Helicopters: n=1,494)
Adapted from: Hart, Conference presentations, 2000/2001

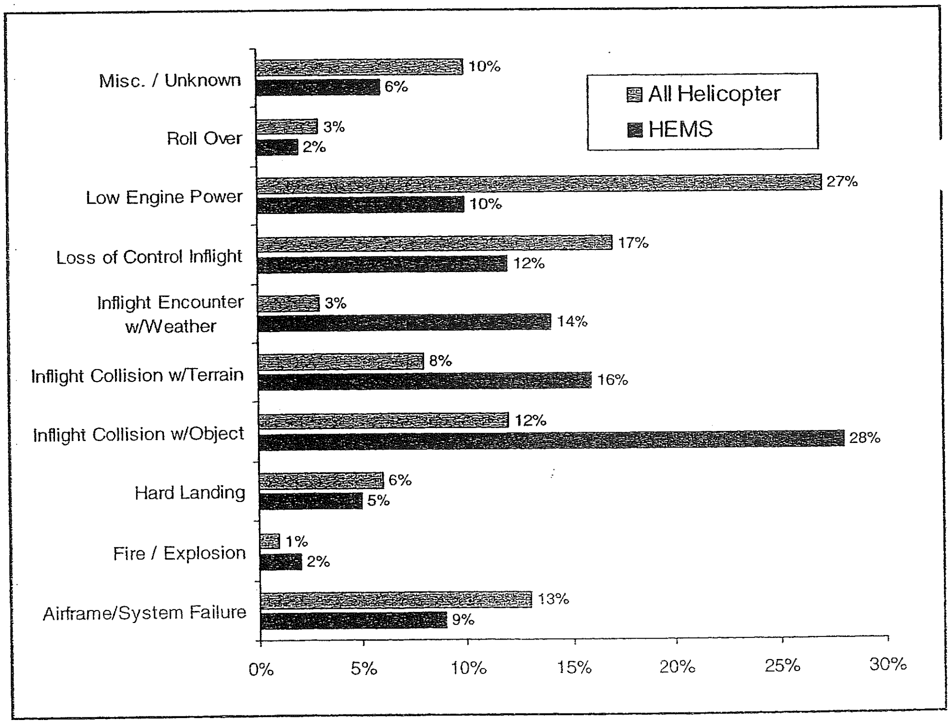


Figure 2–6: First Events (HEMS: n=58; All Helicopters: n=1,494)
Adapted from: Hart, Conference presentations, 2000/2001

Cause and Contributing Factors of Accidents

When the NTSB finalizes their accident reports they try to identify a cause of each accident. This is not necessarily the only event that contributed to the accident. Pilot-related factors (human factors) were cited 50 times in the 58 accidents. These factors included operating with known deficiencies, inadequate pre-flight planning, inability to evaluate the weather, inadvertent flight into IMC, failure to follow procedures, spatial disorientation, lack of experience, and failure to maintain proper speed, altitude, rate of descent or climb, or RPM. Of interest, Hart pointed out that in very few of these accidents was it identified that the pilot deviated from the FARs or company regulations. This is significantly different than the data reviewed earlier in the ASRS report.

Aircraft-related causes of the 58 HEMS accidents were cited 22 times, while fuel-related problems were cited twice. Weather was cited only once.

There are a number of contributing factors that increase the risk for an accident. Many of these are related to weather (e.g., icing conditions, clouds, fog, rain, snow, sleet), which was cited 29 times as a contributing factor in the 58 accidents. Person-related contributing factors were cited 25 times, which included distractions, pressure felt by the pilot, as well as the items listed under "causes." Terrain, which was cited 24 times, was another consideration and flying at night (dusk to dawn) was cited 18 times.

	Total		Non-survivable		Survivable	
	Crashes	Occupants	Crashes	Occupants	Crashes	Occupants
EMS	75	241	24	70	51	171
Non-EMS	147	485	20	50	127	435

Figure 2–7: Survivable and Non-survivable EMS and Non-EMS Crashes
Adapted from: Dodd, unpublished dissertation, 1992

	Serious Back Injuries (%)		Serious Head Injuries (%)		Minor Head Injuries (%)		Internal Injuries (%)		Fractures (%)	
Occupant Location	EMS	Non-EMS	EMS	Non-EMS	EMS	Non-EMS	EMS	Non-EMS	EMS	Non-EMS
Pilot	4.5	10.8	2.3	2.4	0	3.6	0	0	2.3	7.2
Front Seat	15.4	2.7	7.8	5.4	0	2.7	11.5	0	3.8	8.1
Main Cabin	28.6	9.2	14.3	1.3	5.3	1.3	7.1	2.6	10.7	5.3
Patient	14	N/A	7.1	N/A	0	N/A	0	N/A	7.1	N/A

Figure 2–8: Distribution of Injuries in Survivable Crashes—EMS vs. Non-EMS Crashes
Adapted from: Dodd, unpublished dissertation, 1992

FACTORS RELATED TO OCCUPANT CRASH SURVIVAL IN EMS HELICOPTERS

Much of what we have been reviewing has dealt with the associated risks and events surrounding accidents that have curred in the past. It is also essential assess the relative occupational risk to the crewmembers of EMS helicopters. Robert Dodd's 1992 Ph.D. dissertation evaluated the incidence and seriousness of crash-related injuries among EMS helicopter occupants in *survivable* crashes.

The study found that main cabin occupants in EMS helicopters have nearly 4.5 times the risk of serious injury or death in survivable crashes when compared to a comparable population of occupants in the main cabin of non-EMS air taxi helicopters. For front seat occupants, he found that there was no significant difference in injury risk between the two groups. This seemed to support his premise that EMS aircraft modifications, which are generally limited to the main cabin, were directly associated with the risk of injury and may contribute to occupant injury and death in otherwise survival crashes.

For his study, Dodd reviewed 75 EMS accidents from 1978–1983 and 1983–1989 (with 241 occupants) and 7 non-EMS helicopter accidents from 83–1989 with 485 occupants. His comprehensive review and analysis of available reports identified survivable vs. non-survivable crashes and occupants, as seen in Figure 2–7.

Comparing occupant location in survivable accidents with specific injury patterns, Dodd concluded that EMS main cabin occupants were at a higher risk for serious back injuries and serious head injuries. Figure 2–8 compares the percentage of occupants with specific injuries and where they were seated in the helicopter.

Dodd's research included written surveys that were sent to survivors. Twelve injured EMS occupants indicated injuries that were the result of striking medical equipment inside the helicopter during the crash. This equipment included the stretcher, cardiac monitor, medical panel, oxygen tanks, and portable radio.

As part of his research, Dodd evaluated numerous variables to determine how they had influenced injuries. The variables included crash severity, post-crash fire, number of engines, helicopter weight, light conditions, use of shoulder harness, cause of the crash, age, and sex. For each of these variables, he calculated the relative risk of injury for EMS occupants compared to non-EMS occupants in survivable crashes. Dodd found that there was a significantly greater risk of injury (significant relative risk) in HEMS accidents compared to non-EMS accidents: where there was a post-crash fire; in single-engine helicopters; with helicopters weighing < 4,500 pounds; during daylight conditions; with EMS occupants who did not wear a shoulder harness; and mechanical-related crashes. There was a marginal relative risk of injury in helicopters that weighed > 4,500 pounds.

In contrast, he found no significant relative risk of injury in: the absence of post-crash fire; twin-engine helicopters; during dark (night) conditions; or crashes caused by loss of control, wire strikes, or bad weather. Even though significantly more EMS accidents (32%) occurred in bad weather compared to the non-EMS study group (14%), there was not a significant increase in the risk of injury. There was also no correlation between injury and the age or sex of the occupants between the two groups.

Dodd also evaluated the severity of the accidents and classified them as Crash Severity Level 1 (hard landing), Crash Severity Level 2 (hard landing with substantial damage), and Crash Severity Level 3 (high vertical impact or cruise collision with ground). Level 1 accidents resulted in no injuries to EMS occupants and only one non-EMS injury. Level 2 accidents yielded a significant relative risk for passengers in the main EMS cabin, but a non-significant risk for front-seat passengers. In Level 3 accidents, the significant relative risk for main cabin occupants was even greater in EMS aircraft.

Dodd's calculations of accident rates were similar to the NTSB report that had come out four years earlier. He found that EMS helicopters had an accident rate of 11.84 per 100,000 hours of flight. This is more than 2.5 times that of non-EMS air taxi helicopter operations that were found to have an accident rate of 4.43 per 100,000 flight hours. While Dodd did not compare fatal accident rates, he did compare the percentage of occupant fatalities for his two study groups. He found that 32% of the EMS occupants suffered fatal injuries, while only 9% of the non-EMS occupants died —a rate that is 3.5 times greater for the EMS group.

Dodd's report makes a convincing statement for addressing accident survival as well as accident prevention. EMS personnel are injured more frequently and more severely in survivable HEMS accidents when compared to occupants of non-EMS helicopter crashes.

Dodd presented a 1991 study by Crowley that evaluated the use of helmets in survivable military crashes. Crowley found that occupants without helmets were 4 times more likely to suffer a serious head injury and 6 times more likely to suffer a fatal head injury than occupants with helmets. Limiting the comparison to the main cabin increases the risk. Main cabin occupants with no helmet were found to be at 5 times the risk for a serious head injury and 7.5 times the risk for a fatal head injury than their helmeted counterparts. While Crowley's study was based on military data, he suggested that it might also be applicable to survivable HEMS accidents.

Another series of studies for the U.S. Army concluded that back injuries were the most common injury suffered by occupants in survivable helicopter accidents. These results are consistent with Dodd's findings. The Army studies found that shoulder harnesses were an important factor in reducing the incidence and severity of serious back injuries

Dodd concluded that the increased risk of injury to main cabin occupants of EMS helicopters represented an occupational risk that had not previously been addressed in the literature. He concluded that the EMS helicopter was a very hazardous place, even in a survivable crash. Dodd suggests that the use of energy attenuating seats, in combination with lap and double shoulder harnesses, and intelligently designed interiors could dramatically improve occupant injury tolerance.

HELICOPTER ACCIDENT ANALYSIS TEAM

This next study which is not limited to HEMS, reviews a series of helicopter accidents to determine what happened and what could be done to break the chain of events that lead to accidents. The Helicopter Accident Analysis Team (HAAT), was a cooperative effort involving the Department of Defense (DoD) the Federal Aviation Administration/Department of Transportation (FAA/DoT), and the National Aeronautics and Space Administration (NASA). It began in February of 1997, as mandated by the White House Gore Commission on Aviation Safety.

The approach in this analysis is similar to the "Air Medical Accident Analysis" described in Section 1, but this study included EMS and non-EMS helicopters. A *balanced sample* of 34 helicopter accidents was selected from the 1990 to 1996 NTSB database of helicopter accidents and incidents. HEMS accidents selected were those that involved a patient transport mission at the time of the accident

Three subgroups worked independently to address different aspects of these accidents. First they developed a sense of what happened—the ***chain of events*** that led to each of the accidents. Next they identified the ***problems***—issues with respect to the aircraft, environment, pilot actions, maintenance, air traffic control, and the quality of the information in the report itself. Finally, they brainstormed about what might have prevented the accident entirely or mitigated its severity—the ***interventions***. The goal of the HAAT analysis was to propose technology, training, and institutional interventions that might have eliminated one or more "links" in those chains of events, thereby averting an accident or decreasing the severity of an accident that does occur.

Chain of Events

The number of events identified for any particular accident ranged from 5 to 33, with an average of 16 events per accident. This resulted in a total of 536 events. Five different categories of events were identified. Figure 2-9 lists the categories and examples of the events.

Category	Examples of Events
Preliminary events	***Definition:*** Factors that influenced the accident but were not directly related to actions taken by those involved in the accident ***Examples:*** Pilot's health, pilot's experience, adverse weather
Preflight events	***Definition:*** Events that occurred prior to departure of the accident flight that could have influenced the outcome ***Examples:*** Failing to obtain a weather briefing preflight or ensuring that the aircraft had enough fuel
Flight-related events	***Definition:*** Events or actions that occurred during the flight and were associated with the accident ***Examples:*** Continued flight into adverse weather, poor air traffic control vectoring
Emergency-related events	***Definition:*** Events that occurred during the emergency/ accident sequence or precipitated the sequence ***Examples:*** Poor landing site selection, wire strike, fuel starvation
Survival-related events	***Definition:*** Events or actions that did influence, or could have influenced, occupant survival after the accident ***Examples:*** Helmet use, delayed rescue, inoperative ELTs

Figure 2–9: Chain of Events Categories identified by HAAT

Adapted from: Helicopter Accident Analysis Team. Final Report, NASA-Ames Research Center, 1998

Problems

The accident analysis identified the number of problems for each accident, ging from a low of 3 to a high of 21. ere was an average of 16 problems per accident, resulting in a total of 442 entries. Figure 2–10 illustrates the categories of problems identified and specific problems within each category.

Interventions

After identifying the problems, interventions were identified that could have prevented the accident or lessened its severity. The number of interventions identified for individual accidents ranged from 4 to 25, averaging 13 per accident. There were a total of 416 possible interventions identified across all the accidents. Figure 2–11 reviews the categories of interventions and the specific proposals made by HAAT.

The previously presented "Air Medical Accident Analysis" evaluated the effectiveness and feasibility of each of their recommended interventions. That was not done in this study. ead, the final step of the HAAT alysis was the proposal of 26 specific *Safety Investment Areas* that were derived from their identified interventions. Rather than a single statement, each area had identified goals, background, opportunities for reducing future fatalities, research needs, timing, related work, and the primary beneficiaries. Their emphasis was no longer on specific interventions that might have broken the chain of events for a specific accident. Rather, the Safety Investments were more global and goal oriented. Their recommendations included specific goals directed toward the development of research and technology to enhance safety and to improve procedures and practices. Safety Investment Areas were identified in helicopter design and performance, situation displays, pilot aiding and automation, pilot training, improving the flight environment, crash survivability, and the improvent of safety data and analysis.

Problems Associated with...	Problems Identified
Pre-Flight Planning	Aircraft / operating limits not considered Weather or wind not considered Mission requirements / contingencies ignored Pre-flight process inadequate Passenger safety brief inadequate
Safety Culture of the Organization	Management policies / oversight inadequate Safety program / risk management inadequate Helicopter not IFR-equipped Problems with pilot's health not addressed
Inadequate Training or Experience	Emergency training inadequate Special operations training inadequate Training inadequate for inadvertent IMC Pilot inexperienced with area, mission, vehicle
Maintenance	Tools to detect failing parts inadequate Bogus, surplus, unapproved parts used Improper procedures/supervision Inadequate documentation Components used not built to manufacturer's specifications
Infrastructure	Inadequate oversight IFR system incompatible with helicopter missions Part 91 vs. Part 135 passenger-carrying operations Inadequate tower/wire markings
Pilot Judgment and Actions	Sense of urgency led to risk-taking Diverted attention, distraction Flight profile unsafe for conditions Poor cockpit resource management Perceptual judgment errors Procedural errors Pilot control/handling deficiencies Used unauthorized equipment
Communications	Coordination with ground personnel Coordination with ATC Coordination with other pilots
Pilot Situation Awareness	Aircraft position and hazards Aircraft state Local and en route weather
Vehicle Part or System Failures	Main rotor problem Engine failures (partial or total) Gear box failure Tail rotor/tail boom failures
Post-crash Survivability	Safety equipment not installed/failed Passenger/crew survival gear not used Vehicle did not withstand impact Vehicle sank and/or capsized Post-crash fire ELT inoperative/damaged by impact Inaccessible accident site/bad weather No flight following–slow to locate site

Figure 2–10: Problems Identified by HAAT

Adapted from: Helicopter Accident Analysis Team. Final Report, NASA-Ames Research Center, 1998

Categories	Proposed Interventions
Safety Culture Solutions	Adequately equip rotorcraft for mission Develop an inadvertent IMC policy Formalize passenger pre-flight briefing Develop clearly defined company policies
Training Interventions	Basic training materials/syllabus Aeronautical decision-making training Crew resource management training Training to recognize and resolve emergencies Ground personnel training Recovery from IMC/IFR training Simulation facilities for rotorcraft training Training for unique ops/maneuvers/missions
Maintenance Solutions	Non-destructive inspection techniques Improved maintenance procedures and quality control
Helicopter Design and Performance Solutions	Health and Usage Monitoring Systems Real-time performance monitoring Wire cutters/hardened blades Icing protection Miscellaneous design improvements
Helicopter Situation Display Solutions	Ground proximity warning system for rotorcraft Electronic map/position Obstacle detection and alerting Radar alt/distance from ground/water Enhanced/synthetic vision Weather display and alerting
Pilot Aiding and Automation Interventions	Autorotation display/aid Attitude hold/stabilization Automatic flight following PC-based Pre-Flight Planner and PC-based Risk Assess System
Infrastructure Interventions	Operating requirements for commercial rotorcraft Regulations/procedures for inadvertent IMC Review tower/wire marking requirements Navigation/landing systems for rotorcraft Review training and qualification requirements Requirements for company safety program Special operations regulations
Post-Crash Survival Interventions	Improved crashworthiness Crash-survivable ELT Survival equipment Restraint systems Flotation systems Crash-resistant fuel system Underwater egress training
Improved Reporting Interventions	Cockpit voice recorder/flight data recorder Improved NTSB accident forms Improved data acquisition Data dissemination/feedback to industry Inflight audio-visual recording in cockpit

Figure 2–11: Interventions Proposed by HAAT

Adapted from: Helicopter Accident Analysis Team. Final Report. NASA-Ames Research Center, 1998

HEMS VS. OTHER AVIATION OPERATIONS

Background

Generally speaking, there are three major categories of aviation regulated by the FAA. Part 135 corresponds to "air taxi" and is classified as *Scheduled* (commuter flights with fewer than 10 seats) or *Non-scheduled*, which includes air medical transport and other on-demand air taxi services. Part 121 aviation governs the airlines, both scheduled and non-scheduled (charter) airlines. The third category is General Aviation (Part 91), typically characterized by recreational (personal) flying, instructional, business, corporate, public use, and other vital services. Figure 2–12 summarizes the number and types of aircraft that were operated under the different regulations in 1998/1999.

As Figure 2–12 shows, helicopters account for a very small portion of aviation operations. Based upon our 1998/1999 statistics, EMS helicopters accounted for an estimated 5 of all helicopters and approximately 48% of the on-demand helicopters in operation. In 1980 there were an estimated 20,750 HEMS flight hours. By 1990, this increased to approximately 140,500. In 2001, HEMS hours were estimated at nearly 217,500 while all helicopters flew approximately 2.4 million flight hours, general aviation flew 26.2 million hours, Part 135 operations accounted for nearly 3.7 million flight hours, and Part 121 airlines flew 16.7 million hours.

HEMS, a Part 135 on-demand air taxi, is certainly a unique form of aviation. There are some similarities with other 135 operations, but also some similarities with General Aviation (Part 91). In fact, as Hart pointed out in her study, many of the HEMS accidents were operating under Part 91 at the time of their accident (e.g., ferry flight, reposition, instruction).

In general aviation (GA), personal flights are consistently the most dangerous. An estimated 44% of all flying is done for recreational or personal rea- s and results in nearly 65% of the al accidents. In contrast, business flying (i.e., business people who are not professional pilots), accounts for approximately 14% of the GA flight hours, but only accounts for 6% of the fatal accidents. Instructional flying, with 22% of the flight time, results in more than 8% of the fatal accidents. Corporate flying represents only 6% of GA flight hours and had a fatal accident rate of less than 1%. Business and corporate pilots may be more willing to scrub a trip, may fly more reliable equipment, or may have more experience. Likely, it is a combination of all these factors.

In significant contrast to HEMS accidents, nearly 70% of all general aviation (Part 91) accidents are "fender benders" and result in little or no injury. Like HEMS accidents, however, the majority of accidents (more than 70%) were pilot-related. Typically, GA takeoffs and landings account for less than of a typical cross-country flight. wever, an estimated 50–70% of the GA accidents occurred during takeoffs and landings. Like HEMS, weather-related accidents were more likely to be fatal than accidents with any other cause. In 2000, nearly 90% of these weather-related accidents resulted in fatalities.

Raw data and normalized statistics are available from the FAA for the different types of aviation operations. Figures 2–14 to 2–16 provide statistics from 1982 to 2001 with regard to number of accidents (total and fatal), flight hours, and annual accident rates for each category. Figures 2–17 and 2–19 graph the accident rates for side-by-side comparison.

In general, the FAA data for this 20-year period shows:

- Helicopter and general aviation accident rates are much higher than all other aviation operations, followed by non-scheduled Part 135 operations.
- The helicopter accident rate has fluc- ated from a low of 6.17 accidents per 100,000 flight hours to a high of 12.26.
- General aviation has seen a general decrease in its accident rate.
- From 1982–1992, general aviation had the highest fatality rate among the various aviation operations. Beginning with 1993, helicopter operations have had the highest fatality rate in 7 of the last 9 years.
- Scheduled Part 135 operations have a very consistent and low accident rate from 1983 through 1996. The past five years, however, have seen a significant increase in this rate.

	Airlines (Part 121), 1998	On-Demand Air Taxi (Part 135), 1999	General Aviation (Part 91), 1999
Experimental		30	20,493
Piston Single-Engine	167	652	150,081
Piston Twin-Engine	44	1,607	19,469
Turboprop Single-Engine		75	943
Turboprop Multiengine	1,837	860	3,802
Turbojet	5,108	496	6,625
Helicopter	*3*	***746***	***6,701***
Total	7,159	4,466	208,114

Figure 2–12: Aircraft in Operation, 1998/1999

Adapted from: The Nall Report 2001, AOPA, http://www.aopa.org/asf/publications/01nall.pdf and The Nall Report 2000, AOPA, http://www.aopa.org/asf/publications/00nall.pdf

Operation	Percent of Flying (1999)	Percent of Total Accidents (2000)	Percent of Fatal Accidents (2000)
Personal	44.3	67.4	64.4
Instructional	22.1	13.1	8.2
Aerial Application	4.8	6.0	5.0
Business	13.6	4.0	6.1
Positioning	—	1.7	2.3
Ferry	—	1.0	0.3
Public use	2.2	0.7	0.9
Other work use	2.2	1.0	1.2
Aerial Observation	4.1	0.4	0.3
Corporate	5.5	0.4	0.9
Other/unknown	1.1	4.4	10.2

Figure 2–13: General Aviation Accident Data, 1999/2000

Adapted from: The Nall Report, 2001, www.aopa.org/asf/publications/01nall.pdf

A Normalized Statistical Comparison

With all of this data, it is now possible to compare the different types of aviation operations. We have already estimated the accident and fatality rates per 100,000 flight hours for HEMS. These rates can now be included for a more meaningful comparison. It should be noted that we are beginning in 1982 rather than in 1980, as we did with the earlier HEMS graphs.

As the graphs indicate, accident rates for HEMS, all helicopters, and general aviation have always been higher than airline rates. There are many factors that contribute to this difference. In general, these three types of aviation operations involve risks that are not in common with the airlines. These differences include:

- Helicopters and general aviation pilots conduct a wider range of operations, often with less regulation and fewer support services.
- There is a wider variance in pilot qualifications and training.
- There are fewer cockpit resources. Air carrier operations require at least two pilots, while most general aviation and helicopter operation are single pilot.

	U.S. General Aviation						*Helicopter*					
Year	Accidents			Flight Hours	Accidents per 100,000 Flight Hours		Accidents			Flight Hours	Accidents Per 100,000 Flight Hours	
	All	*Fatal*	*Fatalities*		*All*	*Fatal*	*All*	*Fatal*	*Fatalities*		*All*	*Fatal*
1982	3,233	591	1,187	29,640,000	10.90	1.99	255	41	66	2,350,000	10.85	1.74
1983	3,076	555	1,068	28,673,000	10.72	1.94	234	35	55	2,272,000	10.30	1.84
1984	3,017	545	1,042	29,099,000	10.36	1.87	224	38	61	2,495,000	8.98	1.52
1985	2,739	498	956	28,322,000	9.66	1.75	205	36	50	2,154,000	9.52	1.67
1986	2,581	474	967	27,073,000	9.53	1.75	190	39	81	2,625,000	7.24	1.49
1987	2,494	446	837	26,972,000	9.24	1.65	180	28	44	2,283,000	7.88	1.23
1988	2,387	460	797	27,446,000	8.69	1.68	179	21	27	2,707,000	6.61	0.78
1989	2,242	431	768	27,920,000	8.01	1.53	187	30	44	2,829,000	6.61	1.06
1990	2,241	443	767	28,510,000	7.86	1.55	195	25	28	2,392,000	8.15	1.05
1991	2,197	438	799	27,678,000	7.93	1.58	170	30	51	2,756,000	6.17	1.09
1992	2,111	451	867	24,780,000	8.51	1.82	179	41	72	2,282,000	7.84	1.80
1993	2,063	400	740	22,796,000	9.05	1.75	180	37	71	1,833,000	9.82	2.02
1994	2,022	404	730	22,235,000	9.08	1.81	218	44	79	1,777,000	12.26	2.45
1995	2,056	413	735	24,906,000	8.24	1.65	161	25	45	1,961,000	8.21	1.27
1996	1,908	361	636	24,881,000	7.67	1.45	176	32	55	2,120,000	8.29	1.51
1997	1,845	350	631	25,591,000	7.21	1.36	164	28	46	2,084,000	7.87	1.34
1998	1,904	364	624	25,518,000	7.45	1.42	191	34	66	2,138,000	8.93	1.59
1999	1,906	340	619	29,713,000	6.41	1.14	198	31	57	2,171,000	9.12	1.43
2000	1,838	343	594	29,057,000	6.33	1.18	206	35	63	2,472,000	8.33	1.42
2001	1,721	321	553	26,220,000	6.56	1.22	182	29	51	2,381,000	7.64	1.22

Source: www.ntsb.gov/aviation/Table10.htm *Source: www.rotor.com/safety/stats70.01.xls*

Figure 2–14: U.S. General Aviation and Helicopter—Accidents, Fatalities and Rates: 1982 through 2001

	Part 135: Scheduled						*Part 135: Non-scheduled*					
Year	Accidents			Flight Hours	Accidents per 100,000 Flight Hours		*Accidents*			*Flight Hours*	*Accidents per 100,000 Flight Hours*	
	All	*Fatal*	*Fatalities*		*All*	*Fatal*	*All*	*Fatal*	*Fatalities*		*All*	*Fatal*
1982	26	5	14	1,299,748	2.000	0.385	132	31	72	3,008,000	4.39	1.03
1983	16	2	11	1,510,908	1.059	0.132	142	27	62	2,378,000	5.97	1.14
1984	22	7	48	1,745,762	1.260	0.401	146	23	52	2,843,000	5.14	0.81
1985	18	7	37	1,737,106	1.036	0.403	157	35	76	2,570,000	6.11	1.36
1986	14	2	4	1,724,586	0.812	0.116	118	31	65	2,690,000	4.39	1.15
1987	33	10	59	1,946,349	1.695	0.514	96	30	65	2,657,000	3.61	1.13
1988	18	2	21	2,092,689	0.860	0.096	102	28	59	2,632,000	3.88	1.06
1989	19	5	31	2,240,555	0.848	0.223	110	25	83	3,020,000	3.64	0.83
1990	15	3	6	2,341,760	0.641	0.128	107	29	51	2,249,000	4.76	1.29
1991	23	8	99	2,291,581	1.004	0.349	88	28	78	2,241,000	3.93	1.25
1992	23	7	21	2,335,349	0.942	0.300	76	24	68	2,844,000	2.67	0.84
1993	16	4	24	2,638,347	0.606	0.152	69	19	42	2,324,000	2.97	0.82
1994	10	3	25	2,784,129	0.359	0.108	85	26	63	2,465,000	3.45	1.05
1995	12	2	9	2,627,866	0.457	0.076	75	24	52	2,486,000	3.02	0.97
1996	11	1	14	2,756,755	0.399	0.036	90	29	63	3,220,000	2.80	0.90
1997	16	5	46	982,764	1.628	0.509	82	15	39	3,098,000	2.65	0.48
1998	8	0	0	353,670	2.262		77	17	45	3,802,000	2.03	0.45
1999	13	5	12	342,731	3.793	1.459	73	12	38	3,298,000	2.21	0.36
2000	12	1	5	373,649	3.212	0.268	81	22	71	3,553,000	2.28	0.62
2001	7	2	13	330,500	2.118	0.605	72	18	60	3,400,000	2.12	0.53

Source: www.ntsb.gov/aviation/Table8.htm *Source: www.ntsb.gov/aviation/Table8.htm*

Figure 2–15: U.S. Air Carriers Operating Under Part 135—Accidents, Fatalities and Rates, 1982 through 2001
(Since March 20, 1997 only aircraft with fewer than 10 seats)

Part 121: Scheduled Service							Part 121: Nonscheduled Service					
Year	Accidents			Flight Hours	Accidents per 100,000 Flight Hours		Accidents			Flight Hours	Accidents per 100,000 Flight Hours	
	All	Fatal	Fatalities		All	Fatal	All	Fatal	Fatalities		All	Fatal
1982	16	4	234	6,697,770	0.224	0.045	2	1	1	342,555	0.584	0.292
1983	22	4	15	6,914,969	0.318	0.058	1	0	0	383,830	0.261	[illegible]
1984	13	1	4	7,736,037	0.168	0.013	3	0	0	429,087	0.699	[illegible]
1985	17	4	197	8,265,332	0.206	0.048	4	3	329	444,562	0.900	0.675
1986	21	2	5	9,495,158	0.211	0.011	3	1	3	480,946	0.624	0.208
1987	32	4	231	10,115,407	0.306	0.030	2	1	1	529,785	0.378	0.189
1988	29	3	285	10,521,052	0.266	0.019	1	0	0	619,496	0.161	[illegible]
1989	24	8	131	10,597,922	0.226	0.075	4	3	147	676,621	0.591	0.443
1990	22	6	39	11,524,726	0.191	0.052	2	0	0	625,390	0.320	[illegible]
1991	25	4	62	11,139,166	0.224	0.036	1	0	0	641,444	0.156	[illegible]
1992	16	4	33	11,732,026	0.136	0.034	2	0	0	627,689	0.319	[illegible]
1993	22	1	1	11,981,347	0.184	0.008	1	0	0	724,859	0.138	[illegible]
1994	19	4	239	12,292,356	0.146	0.033	4	0	0	831,959	0.481	[illegible]
1995	34	2	166	12,776,679	0.266	0.016	2	1	2	728,578	0.275	0.137
1996	32	3	342	12,971,676	0.247	0.023	5	2	38	774,436	0.646	0.258
1997	44	3	3	15,061,662	0.292	0.020	5	1	5	776,447	0.644	0.129
1998	43	1	1	15,921,102	0.270	0.006	7	0	0	892,333	0.784	[illegible]
1999	47	2	12	16,693,365	0.282	0.012	5	0	0	861,843	0.580	[illegible]
2000	51	3	92	17,474,405	0.292	0.017	6	0	0	820,738	0.731	[illegible]
2001	36	6	531	15,998,000	0.200	0.013	4	0	0	732,700	0.546	[illegible]

NOTE: Effective March 20, 1997, aircraft with 10 or more seats must conduct scheduled passenger operations under part 121.

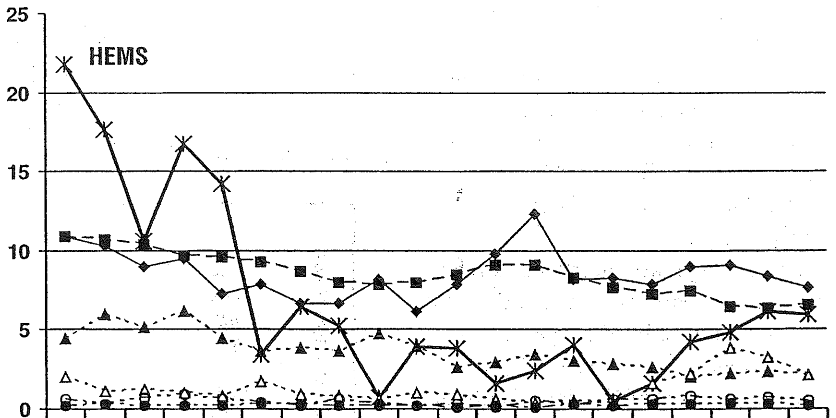
Source: www.ntsb.gov/aviation/Table6.htm

Source: www.ntsb.gov/aviation/Table7.htm

Figure 2–16: U.S. Air Carriers Operating Under Part 121 (Airlines)—Accidents, Fatalities and Rates, 1982 through 2001

- General aviation and helicopters fly to more than 20,000 landing facilities, while the airlines serve only about 700 well-lit airline-served airports.
- Many operations, such as EMS, aerial application, and law enforcement, have special mission-related risks.
- There are more takeoffs and landings per hour, generally the highest risk phases for general aviation and many helicopter operations.

Figure 2–17 shows that the accident rate for HEMS was dramatically higher than for all other aviation operations during the early and mid-1980s. Beginning in1987, we see a sharp decline in the HEMS accident e, which has remained consis- tly below the accident rates for both general aviation and all



	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	'00	'01
—✳— HEMS	21.7	17.7	10.6	16.7	14.2	3.47	6.5	5.28	0.71	3.97	3.81	1.66	2.44	4.08	0.54	1.57	4.27	4.82	6.18	5.97
—◆— Helicopter	10.9	10.3	8.98	9.52	7.24	7.88	6.61	6.61	8.15	6.17	7.84	9.82	12.3	8.21	8.29	7.87	8.93	9.12	8.33	7.64
– –■– – General Aviation	10.9	10.7	10.4	9.66	9.53	9.24	8.69	8.01	7.86	7.93	8.51	9.05	9.08	8.24	7.67	7.21	7.45	6.41	6.33	6.56
- - -▲- - - 135 Nonscheduled	4.39	5.97	5.14	6.11	4.39	3.61	3.88	3.64	4.76	3.93	2.67	2.97	3.45	3.02	2.8	2.65	2.03	2.21	2.28	2.12
- - -△- - - 135 Scheduled	2	1.06	1.26	1.04	0.81	1.69	0.86	0.85	0.64	1	0.94	0.61	0.36	0.46	0.4	1.63	2.26	3.79	3.21	2.12
– -○- - - 121 Nonscheduled	0.58	0.26	0.7	0.9	0.62	0.38	0.16	0.59	0.32	0.16	0.32	0.14	0.48	0.28	0.65	0.65	0.78	0.58	0.7	0.55
– -●- - - 121 Scheduled	0.22	0.32	0.17	0.21	0.21	0.31	0.27	0.23	0.19	0.22	0.14	0.18	0.15	0.27	0.25	0.29	0.27	0.28	0.29	0.2

Figure 2–17: Accidents per 100,000 Flight Hours

helicopter aviation. In addition, from 1987 through 1997, the HEMS accident rate was lower than the overall accident rate for all Part 135 non-scheduled flights 6 of the 10 years. Since 1998, however, the HEMS accident rate has surpassed that of the non-scheduled Part 135 operations each year.

The data in Figure 2–18 represents the average accident rate for the past 20 years (1982–1999), 10 years, and 5 years for the five types of aviation operations, helicopters, and HEMS. Even with the high accident rates of the 1980s, the 20-year average for HEMS is below all helicopter operations and general aviation. For the 10-year average, the HEMS accident rate is less than 50% the rate of all helicopters and general aviation. For the past 5 years, the average accident rate for HEMS has gone up, but remains significantly lower than all helicopter operations and general aviation.

Figure 2–19 compares the fatal accidents per 100,000 flight hours for the various aviation operations. The results are similar to the total accident rates. Initially, the fatality rate for air medical helicopters was equal to or dramatically higher than all other aviation operations. In 1990, however, there were no fatal HEMS accidents. Then from 1992 to 1997, HEMS was consistently below both general aviation and all helicopter operations in fatal accidents. Since 1998, the HEMS fatality rate has been consistently higher.

The average fatal accident rate for the past 20 years, 10 years, and 5 years for the various aviation operations is seen in Figure 2–20. The 20-year average shows HEMS with a high fatal accident rate compared to all other aviation. However, the past 10 years has seen an improvement in the HEMS rate. For the 10-year average, HEMS has had a lower fatality rate than helicopters and general aviation (Part 91). For the past 5 years, however, the average HEMS fatality rate once again exceeds all other aviation operations.

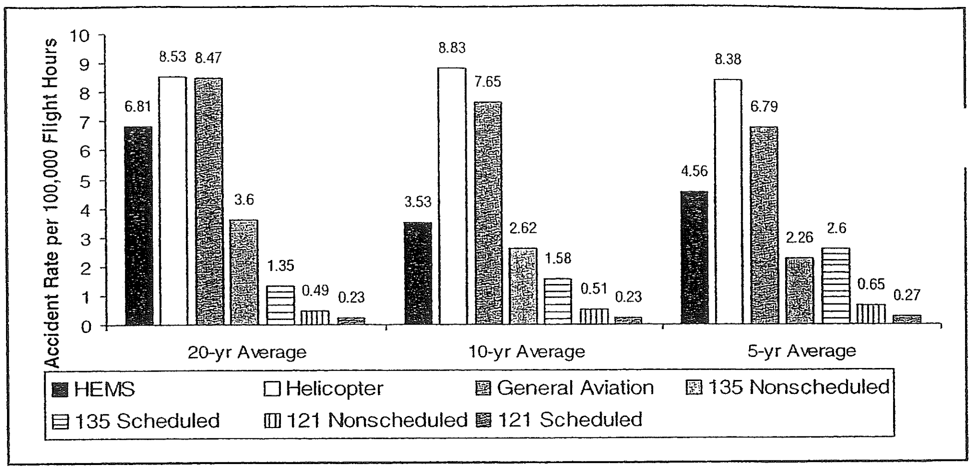
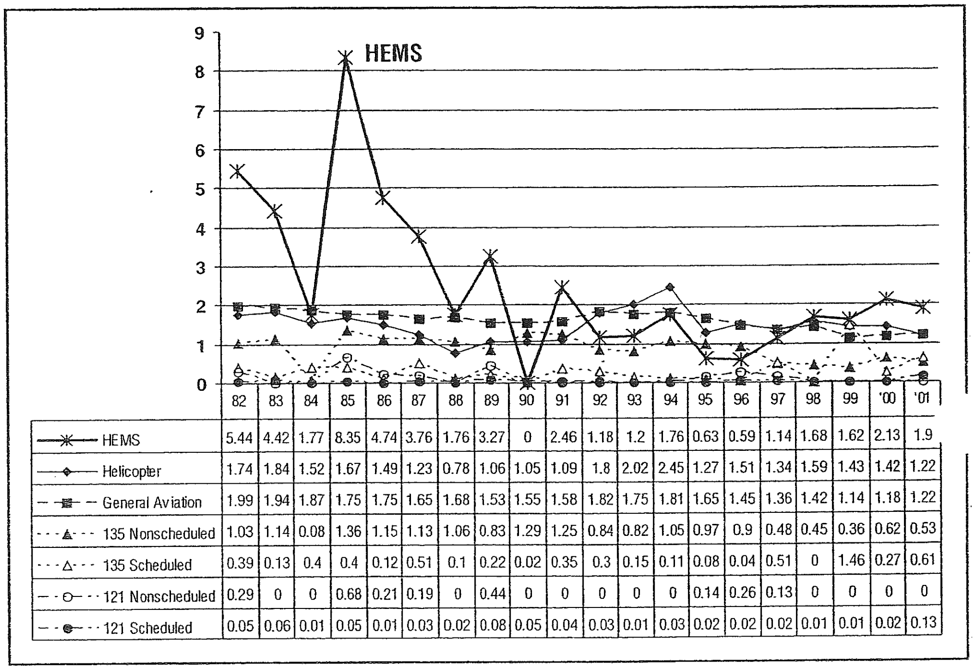


Figure 2–18: Average Accident Rates for Aviation Operations



	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	'00	'01
HEMS	5.44	4.42	1.77	8.35	4.74	3.76	1.76	3.27	0	2.46	1.18	1.2	1.76	0.63	0.59	1.14	1.68	1.62	2.13	1.9
Helicopter	1.74	1.84	1.52	1.67	1.49	1.23	0.78	1.06	1.05	1.09	1.8	2.02	2.45	1.27	1.51	1.34	1.59	1.43	1.42	1.22
General Aviation	1.99	1.94	1.87	1.75	1.75	1.65	1.68	1.53	1.55	1.58	1.82	1.75	1.81	1.65	1.45	1.36	1.42	1.14	1.18	1.22
135 Nonscheduled	1.03	1.14	0.08	1.36	1.15	1.13	1.06	0.83	1.29	1.25	0.84	0.82	1.05	0.97	0.9	0.48	0.45	0.36	0.62	0.53
135 Scheduled	0.39	0.13	0.4	0.4	0.12	0.51	0.1	0.22	0.02	0.35	0.3	0.15	0.11	0.08	0.04	0.51	0	1.46	0.27	0.61
121 Nonscheduled	0.29	0	0	0.68	0.21	0.19	0	0.44	0	0	0	0	0	0.14	0.26	0.13	0	0	0	0
121 Scheduled	0.05	0.06	0.01	0.05	0.01	0.03	0.02	0.08	0.05	0.04	0.03	0.01	0.03	0.02	0.02	0.02	0.01	0.01	0.02	0.13

Figure 2–19: Fatal Accidents per 100,000 Flight Hours

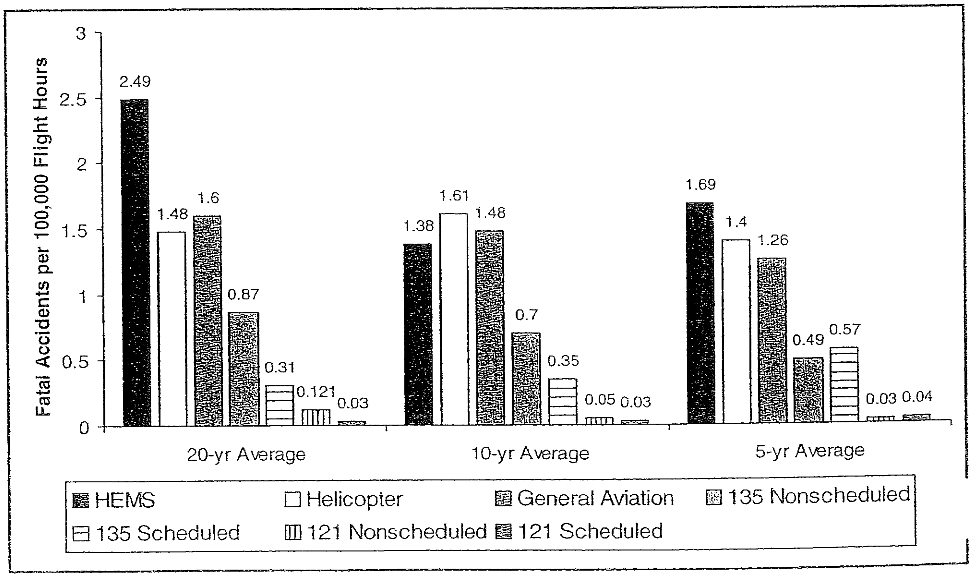


Figure 2–20: Average Fatal Accident Rates for Aviation Operations

U.S. Army Helicopter Accidents

In comparing HEMS to other aviation rations, we have not included any form military aviation. However, much of the research regarding helicopter crashes and survivability has come from U.S. Army studies. It would seem a natural extension of our own study to compare Army accident rates with HEMS.

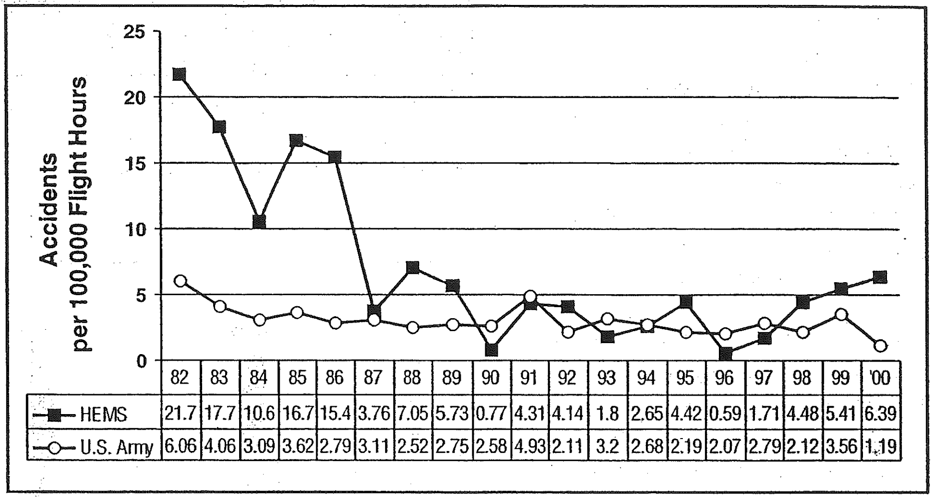
Army Accident Classification

Class A. Damage costs of $1,000,000 or more and/or destruction of an Army aircraft, missile or spacecraft and/or fatality or permanent total disability.

Class B. Damage costs of $200,000 or more, but less than $1,000,000 and/or permanent partial disability and/or five (three as of 2002) or more people are hospitalized as inpatients.

Class C. Damage costs of $10,000 ($20,000 as of 2002) or more, but less than $200,000 and/or non-fatal injury resulting in loss of time from work beyond day/shift when injury occurred and/or non-fatal illness/disability causes loss of time from work.

Adapted from: http://asmis.army.mil/stats/pkg_definitions.class



	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	'00
■ HEMS	21.7	17.7	10.6	16.7	15.4	3.76	7.05	5.73	0.77	4.31	4.14	1.8	2.65	4.42	0.59	1.71	4.48	5.41	6.39
○ U.S. Army	6.06	4.06	3.09	3.62	2.79	3.11	2.52	2.75	2.58	4.93	2.11	3.2	2.68	2.19	2.07	2.79	2.12	3.56	1.19

Figure 2–21: U.S. Army Helicopter Class A and B Accidents vs. HEMS, 1992-2000 (n=77) *Adapted from: U.S. Army Safety Center, Fort Rucker, Alabama*

Information was obtained from the U.S. Army Safety Center at Fort Rucker, Alabama. From 1982–2000, U.S. Army helicopters flew an estimated 22.8 million flight hours worldwide, ranging from a high of 1.55 million hours in 1988 to a low of 753,000 hours in 1998. Total accidents that do not include any combat losses and accidents rates for nine different Army helicopters were also provided. Of these nine types of aircraft, the Army uses two models for medical missions—the UH-1 ("Huey") and the UH-60 ("Blackhawk"). Additional accident information was provided on these two aircraft for 1992–2000, for both the medical (UH1-V and UH-60 MEDEVAC) and non-medical (UH1-AC and UH-60) versions.

During the 18-year period, the U.S. ny recorded a total of 707 Class A and Class B non-combat helicopter accidents. Between 1992–2000, there were a total of 212 accidents. Looking only at the UH-1 and UH-60 from 1992–2000, there were 77 Class A and Class B accidents—11 in MEDEVAC aircraft and 66 in non-medical helicopters. There were an additional 253 Class C accidents reported for the UH-1 and UH-60 helicopters during these 9 years. A total of 44 involved medical helicopters and 209 were non-medical aircraft.

It should be noted that the U.S. Army Accident Classification is very different than the NTSB definitions of accidents and incidents. Clearly, Class A and B would qualify as accidents under the NTSB definitions. Class C however, seems to cross the line between the NTSB definitions of accident and incident.

Unfortunately, our analysis of the Army accident data is limited by several factors. For 1982–2000, we have total flight hours, the number of accidents and the accident rate for the nine aircraft—but only for ss A and B accidents. For the UH-1 nd UH-60, we have raw numbers of accidents for all three classes and for the medevac vs. non-medevac aircraft. However, we lack the corresponding breakdown of flight hours for the medical flights compared to the non-medical flights. Knowing the specific medevac flight hours would have allowed a more meaningful comparison. Finally, we do not have any fatal accident numbers.

Knowing the limitations of our comparison, we have plotted the combined Class A and Class B accident rates along with the HEMS accident rates in Figure 2–21. Over this 19-year period, the Army accident rate was as high as 6.06 accidents per 100,000 flight hours in 1982 and as low as 1.19 in 2000. In the '80s, the HEMS accident rate was consistently higher than the Class A+B accident rate. From 1990–1997, the rates are very similar and since 1998 the HEMS rates have again been higher.

While we do not know the specific accident rates for the Army medevac helicopters, we do know that from 1992–2000, there were six non-medical accidents for every one medevac crash involving the Huey and Blackhawk helicopters. However, if we were to also factor in the Class C accidents, our raw accident numbers would be increased more than four-fold.

Of interest, it should be noted that U.S. Army MEDEVAC missions are always 2-pilot operations. Most flights are "scene" flights and night missions, which account for an estimated half of all medical missions and are aided by night vision goggles (NVG).

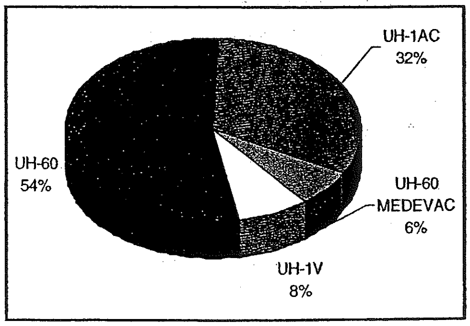


Figure 2–22: UH–60 vs. UH-1 Accidents 1992–2000 (n=77) *Adapted from: U.S. Army Safety Center, Fort Rucker, Alabama*

U.S. Forest Service Aviation Accidents

While the HEMS fatal accident rate as been higher than that of all other types of aviation for the past several years, it is not the most hazardous flying in the United States.

In August 2002, the NBC *Nightly News* reported that piloting Forest Service airtankers was the most dangerous flying in the United States. Since 1950, a total of 156 pilots had lost their lives fighting fires. NBC reported that the accident rate for Forest Service airtankers was found to be 13 per 100,000 hours of flight time. In comparison, they reported that the accident rate of U.S. military combat flight was 11 per 100,000 flight hours while that of civilian aviation was 3.6 per 100,000 flight hours.

Our own research into the Forest Service accident rates found that the reported accident rate of 13 per 100,000 hours of flight time represents a 10-year average for airtankers from 1992 to 2001. During that time, the annual range was from 0 to 51.36. uring that same timeframe, other ixed-wing aircraft (not airtankers) had an average accident rate of 2.70 (range 0 to 15.13) and helicopters had an average of 8.93 (range 0 to 24.55). The 10-year average for all Forest Service aviation was 5.78 accidents per 100,000 flight hours, with a range of 1.58 to 11.67.

Figure 2–23 shows the annual accident rates and fatal accident rates for the four different Forest Service aviation operations compared to HEMS. Figure 2–24 plots the 5-year and 10-year averages for these operations.

Within this 10-year period, HEMS had the highest accident rates and highest fatal accidents in 1999 and 2001. In addition, in 1996, when HEMS had it's second lowest fatal accident rate, the U.S. Forest Service had a rate of zero. As the 5-year and 10-year averages indicate, HEMS is well below the accident rates for helicopters and airtankers used under contract by the U.S. Forest Service, but emains above the rates for fixed-wing aircraft.

	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	5-yr Avg.	10-yr Avg.
Accident rate per 100,000 flight hours												
HEMS	3.81	1.66	2.44	4.08	0.54	1.57	4.27	4.82	6.18	5.97	4.56	3.53
USFS Owned	0	0	6.94	10.11	8.58	0	0	0	7.84	0	1.57	3.35
Fixed-wing	0	15.13	2.22	0	0	0	3.08	0	2.85	3.76	1.94	2.70
Airtanker	19.42	51.36	9.9	24.07	0	0	27.13	0	0	0	5.43	13.19
Helicopter	14.29	8.31	14.22	0	11.01	24.54	4.09	3.97	3.76	5.06	8.28	8.93
Fatal Accident rate per 100,000 flight hours												
HEMS	1.18	1.2	1.76	0.63	0.59	1.14	1.68	1.62	2.13	1.9	1.69	1.38
USFS Owned	0	0	0	10.11	0	0	0	0	0	0	0.00	1.01
Fixed-wing	0	5.04	0	0	0	0	0	0	2.85	0	0.57	0.79
Airtanker	19.42	51.36	9.9	24.07	0	0	27.13	0	0	0	5.43	13.19
Helicopter	0	0	6.09	0	0	6.13	4.09	0	0	0	2.04	1.63

Figure 2–23: Accident Rates for U.S. Forest Service Aviation Operations vs. HEMS, 1992–2001

Adapted from: U.S. Department of Agriculture, Forest Service, http://www.aviation.fs.fed.us/library/fy01avsumm.pdf

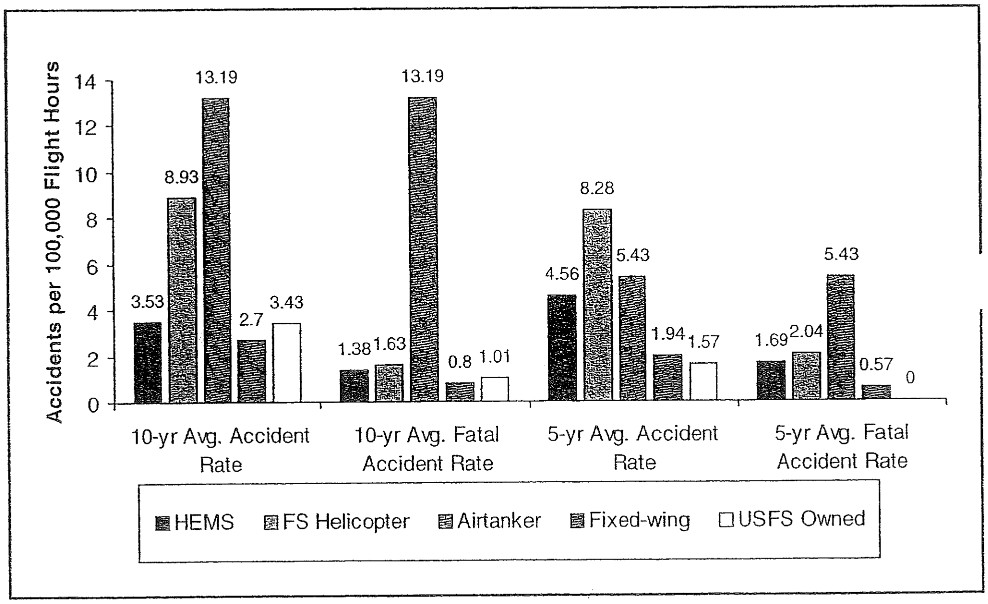
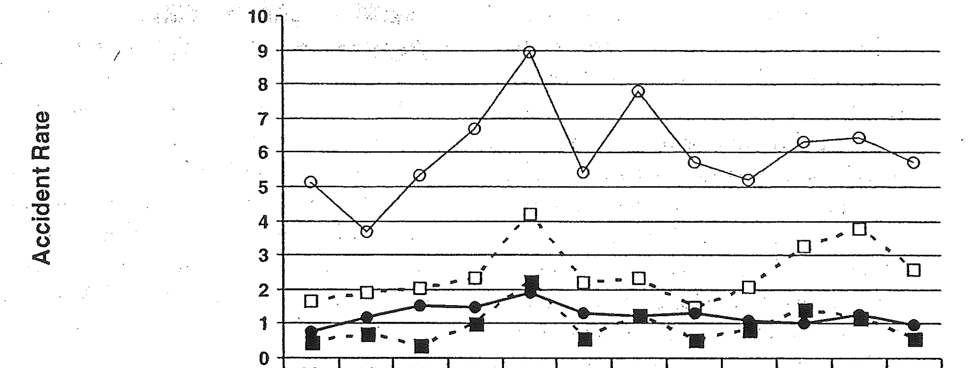


Figure 2–24: U.S. Forest Service Aviation Accidents vs. HEMS, 1992–2001

Adapted from: U.S. Department of Agriculture, Forest Service, http://www.aviation.fs.fed.us/library/fy01avsumm.pdf

SINGLE- VS. TWIN-ENGINE HELICOPTER ACCIDENT RATES

Since 1990, HAI has tracked the accident rate for single-engine vs. multi-engine helicopters, as well as the total helicopter flight hours. In general, it appears that single-engine flight hours have been approximately 3 times that of multi-engine flight hours each year. A dramatic difference is seen in the accident rate per 100,000 flight hours when comparing single- vs. twin-engine helicopters. The fatal accident rate however demonstrates less disparity. In fact, a 1999 study by the Flight Safety Foundation found the fatal accident rate of single- and twin-engine helicopters to be similar. Figure 2–25 charts the total accident and fatal accident rates for single- and multi-engine helicopters.



	90	91	92	93	94	95	96	97	98	99	'00	'01
—○— Single Engine – Total	5.13	3.7	5.32	6.71	8.96	5.41	7.81	5.71	5.23	6.33	6.44	5.74
- -□- - Multi-Engine – Total	1.64	1.91	2.02	2.31	4.18	2.21	2.35	1.5	2.09	3.27	3.78	2.6
—●— Single Engine – Fatal	0.76	1.19	1.53	1.49	1.91	1.33	1.22	1.32	1.12	1.02	1.26	0.98
- -■- - Multi-Engine – Fatal	0.47	0.7	0.4	1.03	2.23	0.6	1.28	0.56	0.84	1.43	1.19	0.6

Figure 2–25: Total Accidents and Fatal Accidents per 100,000 Flight Hours Single- vs. Multi-Engine Helicopters, 1990–2002

Adapted from: Helicopter Association International, http://www.rotor.com/safety/stats70.01.xls

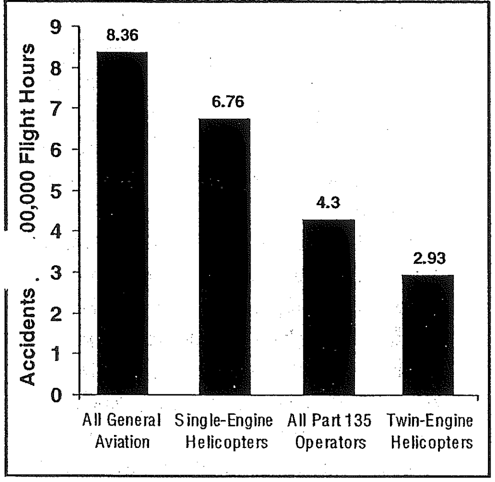


Figure 2–26: Accident Rate Comparison, 1993–1997

Adapted from: Harris, Helicopter Safety, Jan/Feb 1999

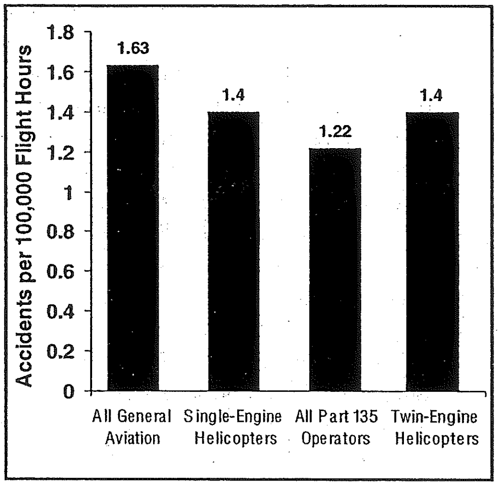


Figure 2–27: Fatal Accident Rate Comparison, 1993–1997

Adapted from: Harris, Helicopter Safety, Jan/Feb 1999

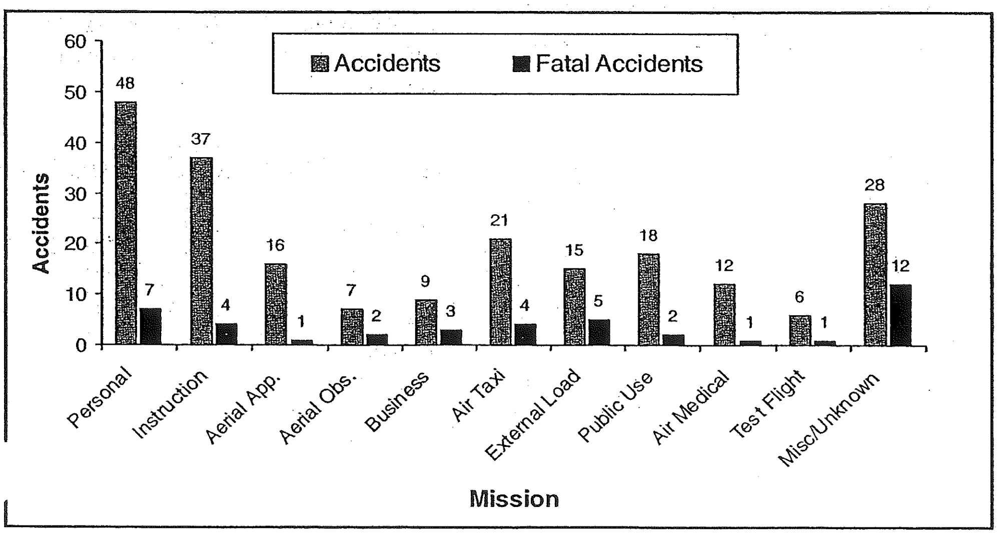


Figure 2–28: Helicopter Accident Statistics, 2001 *Adapted from: http://safecopter.arc.nasa.gov/*

The Flight Safety Foundation study looked at turbine-engine helicopter accidents and compared them with all Part 135 operations and with general aviation. Figure 2–26 shows that the twin-engine helicopter accident rate was lower than the accident rates of general aviation aircraft, single-engine helicopters, and all Part 135 operations.

Nearly half (48%) of the twin-engine helicopter accidents were fatal. From 1993–1997, twin-engine helicopters were involved in 23 fatal accidents, or 1.4 fatal accidents per 100,000 flight hours. Figure 2–27 compares the fatal accident rates for helicopters (single- and twin-engine) general aviation, and air taxis.

HELICOPTER ACCIDENTS, 2001

Year 2001 saw a 12% increase compared to 2000 when looking at all helicopter accidents. During the year, there were 217 helicopter accidents (see Figure 2–28), 42 of which were fatal, killing 105 people. Piston-engine helicopters accounted for 108 accidents, of which 19 were fatal. There were 95 single-turbine accidents (20 fatal) and 13 twin-turbine accidents (3 fatal). Of interest, this NASA "Safecopter" website lists only one of 12 air medical helicopter accidents as fatal.

SECTION 3: A COMPARISON OF RISK

Nothing is completely safe. Everything we do has some type of risk and these risks can never be totally eliminated from any situation. The issue is not one of avoiding risks all together, but rather one of managing risk in a sensible manner.

A 1999 *Time* magazine article, "Life on the Edge," states that "America has embarked on a national orgy of thrill seeking and risk taking." The article focused on the rise of extreme sports like BASE jumping, snowboarding, ice climbing, skateboarding, and paragliding but mentioned other risky activities—and occupations—as well. The article pointed out that Americans were taking greater risks than ever before in many areas. More than 30% of U.S. households owned stocks of some form or another, which was up from 12% just 10 years before. Social behavior had also become more risky, with unprotected sex on the upswing and illicit drugs like heroin on the increase. Finally, the article pointed out that many people assumed various risks in their chosen careers. From the MBAs who were trying to strike it rich in the "dot-com" world; to the 14.5% who voluntarily had left their jobs (highest in a decade) for new opportunities; to the options trader, neurosurgeon, fire fighter, and race car driver—all had chosen to assume a varying degree of occupational risk.

For all of these thrill seekers and risk takers, risk management requires a minimum of common sense and information about the character and magnitude of the risk taken. We must inform ourselves or be educated about the relevant risks and then act accordingly. Where you choose to live, your occupation, chosen modes of travel, recreational activities, or just staying at home—all have risks of accidents, injury, and death.

Determining Risk

Statistics on accidents, injuries, and fatalities are kept for nearly every activity and occupation. With raw data available, we need to be able to calculate the magnitude of a risk. This is especially important if we hope to compare different types of activities. In order to assess and compare risk, the relevant figure needed must be in the form of a ratio, fraction, or percentage. To arrive at these figures—to normalize the data—we need to know two numbers. The numerator of the fraction tells us how many individuals doing a particular activity were either injured or killed over a given period of time. The denominator represents how many people were engaged in that activity—the population at risk. By reducing all risks to ratios in this way we can begin to compare different types of activities and the relative risks. The larger the ratio, the riskier the activity.

There are two other options to normalize this data which are used more commonly by the National Safety Council (NSC). The first is to take the above fraction and normalize it to "1 in X," as in "the odds of something is 1 in X." The other option is to calculate death rates and injury rates per 100,000 persons.

There is risk of injury and death every hour of every day. The NSC estimates that while you make a 10-minute safety presentation, two persons will be the victims of unintentional deaths and approximately 370 will suffer a disabling injury. On the average, there are 12 unintentional-injury deaths and about 2,400 disabling injuries every hour during the year. Figure 3–1 shows a breakdown of the frequency and death rate of the major classifications of accidental deaths and injuries in the United States for 2000.

An individual is nearly twice as likely to be injured at work than in his/her car. Staying at home or going out in public is even worse. You are more than three times more likely to be injured at home or in public than in your car. However, in general, you are six times more likely to die in your car than die due to an accident at work and nearly one-and-a-half times more likely to suffer a fatal injury in your car than at home.

Where you choose to live will also impact your likelihood of dying from an unintentional injury. According to NSC statistics, Massachusetts and Rhode Island boast the lowest accidental death rates among the fifty states. However, if you live in New Mexico, Wyoming, or Alaska (the states with the highest accidental death rate), your chances of an unintentional death are 2.5 to nearly 3 times higher.

HEMS: ANALYZING THE POPULATION AT RISK

With injury and death statistics available for various occupations and types of activities, it would be necessary to determine the size of the "population at risk" in HEMS. To accomplish this—and with no such data available—we must make several assumptions and do various calculations.

Methodology

If one were to try to compare air medical transport to other occupations or "routine" risks to determine either the odds of death in one year or the fatality rate per 100,000 we would need to know two things. The first is the number of HEMS crew fatalities per year. The second would be the number of people engaged in HEMS transport (i.e., the number of HEMS pilots and medical crewmembers) for each year. The number of fatalities is known, but the number of crewmembers in HEMS has never been tracked or even estimated in the literature.

For the purpose of this study, we begin by estimating the average number of crewmembers per helicopter. We can assume that the typical flight crew for each dedicated medical helicopter includes 4 pilots, 6–8 nurses as the primary caregivers, and 10–12 second medical crewmembers (often paramedics, physicians, nurses, respiratory therapists, etc., who fly full- or part-time). Therefore, the average dedicated medical helicopter would have 20 to 24 crewmembers. For the purpose of our calculations, we will use an average of 22 persons.

Class	Severity	One every	2000 Total	Death Rate
All Unintentional	Deaths	5 minutes	97,300	35.3
	Injuries	1.5 seconds	20,500,000	
Motor-Vehicle	Deaths	12 minutes	43,000	15.6
	Injuries	14 seconds	2,300,000	
Work	Deaths	102 minutes	5,200	1.9
	Injuries	7 seconds	3,900,000	
Home	Deaths	18 minutes	29,500	10.7
	Injuries	4 seconds	7,100,000	
Public (nonmotor-vehicle)	Deaths	24minutes	22,000	8.0
	Injuries	4 seconds	7,300,000	

Figure 3–1: Unintentional Deaths and Injuries, 2000

Adapted from: National Safety Council, http://nsc.org/library/rept2000.htm

A review of the air medical literature showed there was no documentation as to the number of dedicated EMS helicopters from 1981 to 1991. Our Internet *htweb* survey provided us with a fairly curate number of dedicated helicopters as well as HEMS programs for the year 2000. Assuming a steady annual increase in the number of aircraft between 1991 and 2000, we are able to predict the number of helicopters dedicated to the HEMS mission for each year. For 2001, we factored in the percent increase as determined from our operator and manufacturer survey.

We now have the necessary information to determine the approximate size of the population at risk. In 2001, there were an estimated 400 dedicated medical helicopters. Multiplying this figure by 22 crewmembers, we can estimate that the population at risk is approximately 8,792. Using this figure and knowing the number of crewmember deaths attributed to HEMS accidents, we are now able to compare some annual statistics in a more meaningful manner. In addition, we will be able to compare HEMS risk with other occupations and activities.

It is important to realize that in esti- ting exposure in this method, we are doing so for the *average* crewmember and the *average* flight program. The National Safety Council points out that predicting the rate for potential injury or death is strongly dependent upon the length of exposure to a particular activity for the specific population at risk. This would be similar to comparing the potential exposure rate for full-time vs. part-time HEMS personnel; four pilots vs. 6–8 nurses; programs that fly once a day vs. those that fly several times a day; programs that fly short distances to those that fly much further, and so on. When we normalize the raw data, it does not take into account the *amount* of exposure for an individual during the year. For this study, we are basing our calculations on the average program, which in 2001 transported approximately 882 patients, flying an estimated 957 hours over the course of the full year, and all crewmembers (pilots and medical crewmembers) flying an equal amount of time.

Results

Fatality statistics for HEMS personnel are presented in four different formats. In each case, the number of crew fatalities was determined for each year. From the total 171 HEMS fatalities, 21 patient fatalities, 7 dual-purpose aircraft crewmember fatalities and 6 other fatalities were removed from the appropriate years leaving only dedicated HEMS crew fatalities for our comparison. Figure 3–2 depicts the number of HEMS personnel who have died each year since 1980. The fatalities for 2002 (as of September 30, 2002) are included in this graph but are not included in any of our calculations. As the graph clearly shows, 2002 has had more crew fatalities than any year in HEMS history. Figure 3–3 shows the various calculations and the results used to determine the fatality rates.

The National Safety Council routinely normalizes fatality data to a death rate per 100,000 population at risk in a given year. Over the 21 years reviewed for this portion of the study (1981–2001), the HEMS population has grown from approximately 858 to 8,792. While this growth seems impressive, this is still a

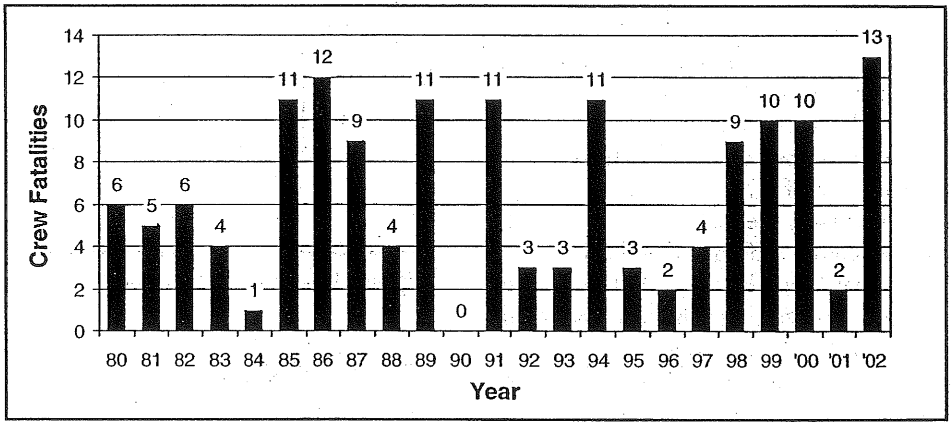


Figure 3–2: HEMS Crew Fatalities per Year, 1980–2002*
(as of September 30, 2002)

		1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals
1	# of Helicopters	39	*45*	*62*	*75*	*91*	*119*	*151*	*184*	*195*	*213*	*231*	*225*	242	259	276	293	309	326	343	360	377	400	
2	Calc. Total Crew	858	990	1364	1650	2002	2618	3322	4048	4290	4686	5082	4950	5322	5693	6065	6436	6808	7179	7551	7922	8294	8792	185064
3a	Crew Fatalities	6	5	6	4	1	11	12	9	4	11	0	11	3	3	11	3	2	4	9	10	10	2	137
3b	Dual-Purpose Crew Fatalities										2		2							3				7
4	Patient Fatalities	1	1	1	0	1	1	1	1	1	3	0	3	0	2	0	0	1	1	2	0	1	0	21
5	Other Fatalities								2				1										3	6
6	Total Fatalities	7	6	7	4	2	12	13	12	5	16	0	17	3	5	11	3	3	5	14	10	11	5	171
7	Crew Fatality Rate	0.70%	0.51%	0.44%	0.24%	0.05%	0.42%	0.36%	0.22%	0.09%	0.23%	0.00%	0.22%	0.06%	0.05%	0.18%	0.05%	0.03%	0.06%	0.12%	0.13%	0.12%	0.02%	0.196%
8	1 in______	143	198	227	413	2002	238	277	450	1073	426	N/A	450	1774	1898	551	2145	3404	1795	839	792	829	4396	1158
9	per 100,000	699	505	440	242	50	420	361	222	93	235	0	222	56	53	181	47	29	56	119	126	121	23	196
10	No Injuries	2	6	17	9	8	11	19	0	15	8	4	9	4	0	4	13	0	5	12	18	13	18	195
11	Injuries Serious	0	0	0	3	3	5	3	0	5	4	0	0	10	3	1	0	0	0	5	6	0	8	56
	Minor	0	3	0	3	8	11	10	1	6	3	0	0	4	3	3	5	0	1	0	0	7	5	73
13	Total Injuries	0	3	0	6	11	16	13	1	11	7	0	0	14	6	4	5	0	1	5	6	7	13	129
14	Injury Rate	0.0%	0.30%	0.00%	0.36%	0.55%	0.61%	0.39%	0.02%	0.26%	0.15%	0.00%	0.00%	0.26%	0.11%	0.07%	0.08%	0.00%	0.01%	0.07%	0.08%	0.08%	0.15%	0.16%

Figure 3–3: Fatalities and Fatality Rates

very small sampling to translate to a ratio per 100,000. As Figure 3–4 shows, with such a small population base, each fatali- has a significant impact on the fatality ate. In this format, the range for the fatality rate is from 0 to 699 per 100,000. With such a wide range, a 22-year average is calculated that will be used when we compare HEMS to other risks. The average annual death rate over the 22 years is 196 per 100,000 crewmembers.

Another way to look at the relative risk of HEMS transport is in the form of a ratio—dividing the number of fatalities by the number of crewmembers for each year. Since this uses the same data, but in a slightly different equation, the graph would look essentially the same as Figure 3–4. For this annual comparison (Figure 3–3, Line 7) the range is from 0.00% to 0.70%, with a 22-year average of 0.196%. The higher the percentage, the greater the apparent risk in that particular year.

The final relationship that is used to compare the annual number of HEMS crew fatalities is in terms of "odds." For example, in 2001 there were only two crew deaths out of an estimated crew opulation of 8,792. Looking solely at the numbers, the odds to an individual crewmember suffering a fatal accident that year would be considered to be 1 in 4,396. Contrasting this with what could be considered our riskiest year (1980), there were 6 crew fatalities out of an estimated 858 crewmembers industry-wide. This would correspond to fatality odds of 1 in 143. Excluding 1990 when there were no fatalities, the average odds per year over the 22-year period are 1 in 1,158. Figure 3–5 illustrates the odds of a fatality over the study time period.

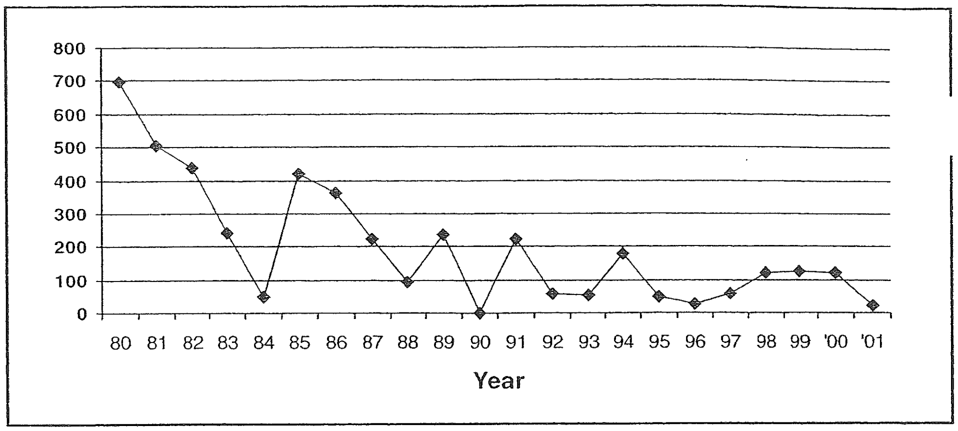


Figure 3–4: HEMS Fatality Rate per 100,000 Personnel, 1980–2001

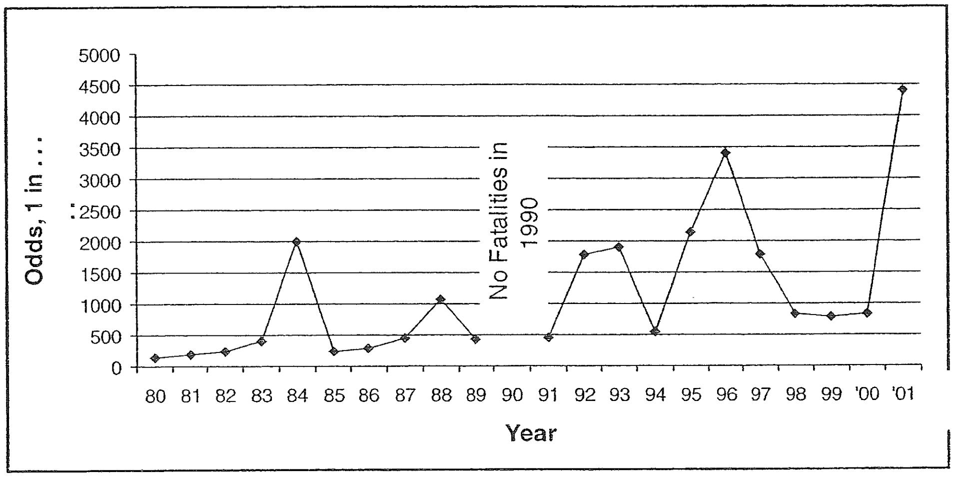


Figure 3–5: Odds of a Fatality for HEMS Personnel, 1981–2001

COMPARING HEMS TO OTHER RISKS

To further illustrate the risk related to HEMS transport, we can compare and contrast the above numbers with other activities, other types of accidents, and other causes of death. Taking into consideration the wide range of fatality rates and odds that we have estimated for each ear in HEMS, the calculated *averages* will be used in subsequent comparisons.

Cause of Death – An Overview

Since 1921, the National Safety Council has been a source of accurate, comprehensive, and objective statistics on unintentional injuries, their costs, trends, and other characteristics. Accidents and unintentional injuries generally rank as the fifth leading cause of death worldwide behind heart disease, cancer, stroke, and COPD.

The NSC provides statistics looking at the total number of deaths and the relative death rate for various unintentional deaths per 100,000 population. The leading five causes of fatal unintentional injuries (motor vehicle accidents, falls, poisoning, drowning and choking) have been the same from 1970 through 1998 (1998 is the last year this data was available). Together, these five categories of injury accounted for nearly 80% of all accidental deaths (77,951 of the 97,835) in 1998. Figure 3–6 identifies the leading causes of accidental death, number of deaths, and death rate for 1998. In addition, we have included data on other causes of death (heart disease, cancer, and stroke) as well as a comparison to HEMS.

As you can see the 22-year average fatality rate for HEMS is very high. When you consider the average annual death rate over the 22 years reviewed, HEMS is surpassed only by heart disease and cancer when the data is normalized per 100,000 persons.

What are the Odds...

The NSC reports that motor-vehicle accidents cause more accidental deaths in the United States than any other unintentional injury. Looking at the

Cause of Death (in rank order)	Deaths, 1998	Death Rate Per 100,000
All Causes, all ages	**2,337,256**	**864.9**
Heart Disease	724,859	268.2
ncer	541,532	200.4
HEMS *(range over a 22 year period: 0–699 per 100,000)*		***196***
Stroke	158,448	58.6
Chronic obstructive pulmonary diseases (COPD)	112,584	41.7
All Accidental Deaths	**97,835**	**36.2**
(Following is a select listing of accidental deaths)		
Transport Accidents	45,774	16.9
Motor-vehicle	*43,501*	*16.1*
Air and space transport	692	0.3
Water transport	692	0.3
Railway	*515*	0.2
Misc.	*374*	*0.1*
Falls	16,274	6.0
Poisoning by solids, liquids, gases, vapors	10,255	3.8
Drugs, medications, and biologicals	9,838	3.6
Drowning	3,964	1.5
Choking, Inhalation, ingestion of food or other object	3,515	1.3
Fire and flames	3,255	1.2
Complications/misadventures of surgery/medical care	3,228	1.2
Natural and environmental factors	1,521	0.6
Firearm, missile	866	0.3

Figure 3–6: Leading Causes of Death, 1998

Adapted in part from: National Safety Council, Injury Facts 2001 Edition

Type of Accident or Manner of Injury	Deaths, 1998	One-year odds	Life-time Odds
EMS Accidents (22-year average)		***1,158***	
Total deaths due to injuries	150,445	1,796	23
All Accidental Deaths	97,835	2,762	36
Transport Accidents	45,774	5,904	77
Motor-vehicle	43,501	6,212	81
Railway	515	524,753	6,842
Other road vehicle	235	1,149,991	14,993
Water transport	692	390,532	5,092
Air and space transport	692	390,532	5,092
Poisoning by solids and liquids	10,255	26,353	344
Poisoning by gases and vapors	546	494,960	6,453
Complications, misadventures of surgical, medical care	3,228	83,720	1,092
Falls	16,274	16,606	217
Fire and flames	3,255	83,025	1,082
Natural and environmental factors	1,521	177,678	2,317
Excessive heat	375	720,661	9,396
Excessive cold	420	643,448	8,389
Lightning	63	4,289,651	55,928
Cataclysmic storms, and floods	204	1,324,745	17,272
Drowning, submersion	3,964	68,176	889
Inhalation and ingestion of food	1,147	235,613	3,072
Inhalation and ingestion of other object	2,368	114,125	1,488
Mechanical suffocation	1,070	252,568	3,293
Struck by falling object	723	373,787	4,873
Machinery	1,018	265,470	3,461
Adverse effects of drugs in therapeutic use	276	979,159	12,766
Hanging, strangulation, and suffocation	5,726	47,197	615
earms	17,424	15,510	202

Figure 3–7: Odds of Death Due to Unintentional Injury, Selected Causes, 1998 ("1 in _____")

Adapted in part from: National Safety Council, http://nsc.org/lrs/statinfo/odds.htm

odds, an annual risk of death of 1 in a million is equivalent to the risk of dying in a car accident if you travel in your car one mile a week for a full year. Driving (or riding) 10 miles per week in an auto increases your annual risk of dying in an MVA to 1 in 100,000. If you increase your weekly driving to 100 miles, your annual risk of death is now 1 in 10,000, while at 1,000 miles per week our odds of dying in a car accident is 1 in 1,000.

The NSC often fields questions about "odds." For example, "What are the odds of dying in a plane crash or being killed by lightning?" In response to questions like this, the NSC has determined the "Odds of Death Due to Injury" in the United States for various activities. For 1998 (the most recent year of these statistics) the one-year odds were calculated by dividing the 1998 population by the number of recorded deaths from specific injuries that year. To determine the lifetime odds, the NSC took the one-year odds and divided them by the life expectancy of a person born in 1998, which is 76.7 years. The NSC also published death and injury rates per 100,000 for various occupations, activities, and modes of travel.

For 1998, the NSC determined that the odds of dying from an injury (intentional or unintentional) during that year were 1 in 1,796. They also determined that the lifetime odds of dying from an injury for a person born in 1998 were 1 in 23. Looking only at accidental (unintentional) deaths in 1998, the odds decrease to 1 in 2,762 in that year and to 1 in 36 lifetime. Figure 3–7 shows the 1998 odds of death in the United States due to an unintentional injury for various causes. Included in the table are the average one-year odds for a HEMS crewmember to die in a fatal crash. As you can see, the odds of suffering a fatality in HEMS exceed that of motor-vehicle accidents and all other accidental deaths.

As previously discussed, one of the problems with data that is normalized in this fashion is that it does not take into account the true *amount* of exposure during the year. It assumes all exposures are equal. A more accurate approach would be to determine the exposure (time, etc.) that might result in a specified risk that can be compared to other activities.

We have determined that in HEMS there is an average one-year risk of death of 1 in 1,158. *The Book of Risks* has identified several activities that produce a 1-in-1,000 risk of death. In the 22-year HEMS study period an estimated 3,002,176 total hours have been flown. Adding together the estimated number of crewmembers each year yields a total of 105,922. This corresponds to an average exposure of 28.3 hours of flight time producing the estimated odds of 1-in-1,158. Adjusting the ratio to 1-in-1,000, we get an average exposure of 32.9 hours.

Activity	*Time/Effort Involved*
Rock climbing	25 hours
HEMS transport	***32.9 hours***
Skydiving	50 hours
Driving a motorcycle	55 hours
Skiing	340 hours
Flying on a scheduled airline	1,200 hours
Driving a car	52,000 miles

Figure 3–8: Activities Producing a 1-in-1,000 Risk of Death

Adapted in part from: Laudan, The Book of Risks, 1994.

HEMS: The Risk to the Patient

There is some level of risk related to all aspects of healthcare—every procedure performed, every medication dispensed, and every patient transported. The possibility of adverse events or medical errors represents a significant risk to each and every patient.

In *Human Error*, James Reason defines an error as "the failure of a planned action to be completed as intended (i.e., error of execution) or the use of a wrong plan to achieve an aim (i.e., error of planning)." An accident represents an adverse outcome after an error.

The results of the "1991 Harvard Medical Practice Study" concluded that 3.7% of New York hospitalizations resulted in adverse events, of which 13.6% led to death. A subsequent study published in 1999 found that in Utah and Colorado, 2.9% of the hospital admissions experienced an adverse event, with 6.9% of these resulting in a fatality. According to the Institute of Medicine publication, with over 33.6 million admissions to U.S. hospitals in 1997, the results of these two studies would suggest that between 44,000 and 98,000 Americans die in hospitals each year as a result of medical errors.

To put these figures in perspective, this would be roughly equivalent to the crash of a jumbo jet carrying 500 passengers every 2–4 days. In addition, normalizing the data yields a death rate between 131 and 292 per 100,000 patients due to medical errors.

It is noted that the total number of deaths and corresponding death rate is significantly different than the statistics presented for "complication of surgery/medical care" that are listed in Figure 3–6. The National Safety Council death rate is based upon the reported number of deaths in this category compared to the entire U.S. population. The researchers of the two cited studies based their estimates upon a comprehensive review of a sampling of medical records for adverse events. The estimated number of deaths was then calculated for the number of annual *patients* (1997) rather than the entire population. According to the U.S. Department of Commerce, the population in the United States in January 1997 was 266,490,000 people. Normalizing the estimated number of deaths from the New York and Utah/Colorado studies for the entire U.S. population yields a death rate per 100,000 between 16.5 and 36.8 due to medical errors. This is still significantly higher than the NSC rate of 1.2.

While air medical *transport* is not a medical *treatment* and aviation accidents would not be considered a medical error, some could argue that these accidents represent an adverse event in the healthcare environment. In our 22-year study, we estimate that a total of 2,745,207 patients have been flown by HEMS. Over this same time period, 21 patients have lost their lives in HEMS accidents. This corresponds to a death rate of 0.76 per 100,000 patients flown. This takes into account only fatal injuries as a result of helicopter accidents and does not address any medical errors or other adverse events that could take place during transport. Based upon these figures, it would appear that there is a far greater risk to the patient of dying from an adverse event while hospitalized than from an accident aboard a medical helicopter.

Occupational Risks: Deaths and Injuries in the Workplace

In 2000, there were 5,200 workplace accidental fatalities, while an additional 3.9 million American workers suffered disabling injuries on the job. The NSC reports an average death rate across all industries at 3.8 per 100,000 workers, with mining and agriculture having the highest rates. Figure 3–9 shows that if HEMS "workers" were compared to the published NSC data, the average annual HEMS death rate is approximately nine times greater than the riskiest industries tracked by the NSC. However, it must be pointed out that this comparison is greatly distorted when you consider the small HEMS "population." Even in 2001, with our largest estimated number of crewmembers, 2 fatalities resulted in a death rate of 23 per 100,000.

The picture changes dramatically if you look at the rate of injuries, not just

Industry	Workers	Deaths	Death Rate[1]	Disabling Injuries	Injury Rate
All industries	136,402,000	5,200	3.8	3,900,000	2.86%
HEMS (22 yr. Avg)			***196***		**0.16%**
Agriculture	3,380,000	780	22.5	130,000	3.85%
Mining, quarrying	520,000	110	21.2	20,000	3.85%
Construction	8,949,000	1,220	13.6	470,000	5.25%
Manufacturing	19,868,000	660	3.3	630,000	3.17%
Transportation and public utilities	8,084,000	930	11.5	380,000	4.70%
Trade	27,723,000	420	1.5	750,000	2.71%
Services	47,611,000	630	1.3	940,000	1.97%
Government	20,267,000	450	2.2	580,000	2.86%

Figure 3–9: U.S. Unintentional Work-Related Injuries and Deaths, 2000

[1] Per 100,000 workers. *Adapted in part from: National Safety Council, Injury Facts 2001 Edition*

fatalities. The overall injury rate for all industries is 2.86%, ranging from 1.97% to 5.25% of the workers. Over the 22- period, the injury rate for HEMS ges from 0.0% to 0.61%, with an average of 0.16%. This injury rate takes into account only injuries that were suffered in helicopter accidents. It does not take into account any other etiology of disabling injury (e.g., back injury, falls) that could afflict an air medical crewmember while on duty.

A Pittsburgh study by Doyle et al., however looked at occupational injuries in air medical transport. Presented at the 2002 Critical Care Transport medicine Conference (CCTMC), this 3-year study found that the risk per flight of a crewmember sustaining a reportable injury is very low. A total of 16,062 flights resulted in only 86 injuries. However, Doyle also concluded that of the 140 flight personnel, 59% had sustained a reportable injury.

Although industries differ, the types of injuries that occur are common. Figure 3–10 shows the various mechanisms of injury and the percent seen in all industries. As this chart clearly shows, there inherent risks to all occupations that could result in injuries or death. In many ways the risks to health care providers may be similar to other professions, but there may also be greater risk in certain areas. For HEMS personnel, flying is indeed one of those risks. Health care workers, including HEMS personnel, may be exposed to other risks as well.

Violence in the workplace is an all too common problem, with homicide being the leading cause of occupational death among all workers in the United States. It is estimated that 1,000 deaths in the workplace are due to assault each year. Unfortunately, health care workers are not immune to work-related attacks.

According to a 1998 OSHA Publication, more assaults occur in the health care and social services industries than in any other. They cited Bureau of Labor Statistics (BLS) data that showed health care and social service workers having the highest incidence of injuries due to assault. According to one study by odman et al., in 1994, between 1980 1990, 106 occupational violence-related deaths occurred among health care workers, including 27 pharmacists, 26 physicians, 18 registered nurses, 17 nurses' aides, and 18 health care workers in other occupational categories. A separate study using the National Traumatic Occupational Fatality database reported that there were 69 nurses killed at work between 1983 and 1989.

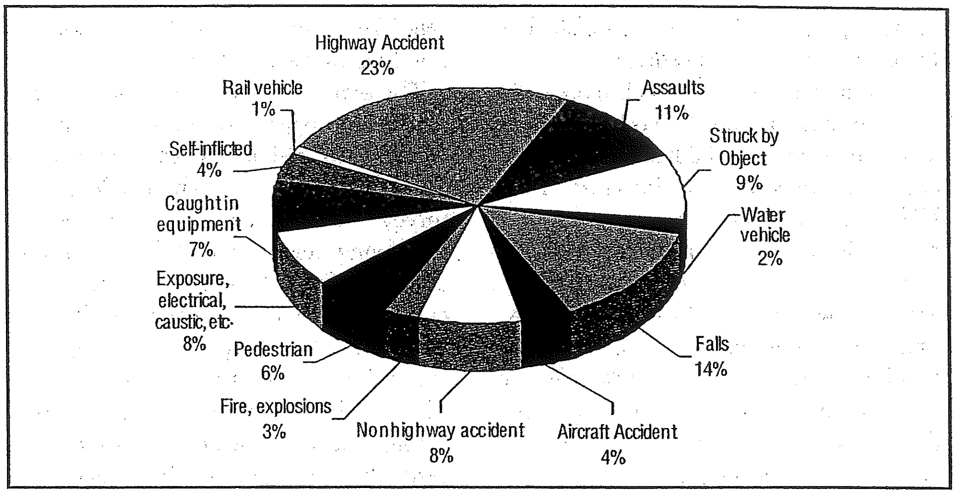


Figure 3–10: Fatal Occupational Injuries by Event, 2001
Adapted from: Bureau of Labor Statistics, http://www.bls.gov/news.release/cfoi.t03.htm

In a 1998 California study, they found that assault, hostage taking, rapes, robbery, and violent actions resulting in death were reported in emergency rooms, mental health hospitals and clinics, and social service offices. A 1983 study by Conn and Lion found that assaults by patients in the hospital setting occurred in psychiatric units (41%), emergency rooms (18%), medical units (13%), surgical units (8%), and even pediatric units (7%). A 1988 study by Lavoie et al., investigated 127 large, university-based hospital emergency departments and reported that 43% had at least one physical attack on a medical staff member per month. Seven percent of the reported acts of violence over a 5-year period resulted in death.

Violence in the emergency department (ED) has seen an increase in recent years. ED personnel face a significant risk of injury from assaults by patients and are often abused by relatives of patients or other persons associated with the patient. A study in the *Journal of Emergency Nursing* by Erickson and Williams-Evans found that 82% of nurses surveyed reported they had been assaulted during their careers—many going unreported. Stultz, in 1993 reported that nurses were the most frequent targets of assault and the greatest percentage (25%) of assaults occurred in the ED. Of 51 homicides involving health care workers, 23% were in the ED.

Unfortunately, air medical personnel are not immune to violent assaults. In January 2002, two flight crewmembers heard a motor vehicle collision on the street adjacent to their base. Upon approaching the vehicle to assist the driver, the two flight team members were shot—one fatally.

Health care workers are exposed to other dangers as well, with the risk of needlestick injury and the transmission of bloodborne pathogens is an industry-wide concern. These injuries can result in serious and potentially fatal infections from the hepatitis B virus (HBV), hepatitis C virus (HCV), or human immunodeficiency virus (HIV).

In the United States, there are more than 8 million health care workers in hospitals and other health care settings. Estimates suggest that 600,000 to 800,000 needlestick injuries occur annually, with about half going unreported. A 1999 study by the National Institute for Occupational Safety and Health estimates that in the average hospital, workers will incur approximately 30 needlestick injuries per 100 beds per year.

In the United States, between 1985 and 1999, there were 55 "documented" cases and 136 "possible" cases of occupational HIV transmission to health care workers. Combined data from more than 20 worldwide studies of health care workers exposed to HIV-infected blood found an average transmission rate of 0.3% (21 infections in 6,498 exposures).

HBV infections occur much more commonly in health care workers. In 1995 alone, an estimated 800 health care workers became infected with this virus. The HBV transmission rate after a single needlestick exposure ranges from 6 to 30% if the health care worker is not immune to HBV. However, treated with hepatitis B immune globulin and initiating the hepatitis B vaccine is more than 90% effective in preventing HBV infection. About one-third to one-half of persons with acute HBV infection develop symptoms of hepatitis. Most acute infections resolve, but 5% to 10% of patients develop chronic HBV infection that carries an estimated 20% risk of dying from cirrhosis and 6% risk of dying from liver cancer.

Hepatitis C virus infection, the most common chronic bloodborne infection in the U.S., is prevalent in 1 to 2% of the general population. Of the acute HCV infections that have occurred annually, 2% to 4% have been in health care workers exposed to blood in the workplace. Unlike HBV, chronic infection develops in 75 to 85% of patients, with active liver isease developing in 70%. Of the patients with active liver disease, 10% to 20% develop cirrhosis, and 1% to 5% develop liver cancer. On the average, 1.8% of the health care workers with percutaneous exposure to HCV become infected.

Another potentially dangerous and risky endeavor for many occupations, especially health care workers, is rotating shift work. Investigators have shown that disruptions in circadian phases due to rotating shift work are associated with decreased performance, lapses of attention, and increased reaction time. In 1992, Gold et al., found that nurses on rotating schedules reported more "accidents" (including on-the-job errors, on-the-job personal injuries, and auto accidents due to sleepiness) than did nurses on other schedules.

Sleepiness has been blamed for approximately 200,000 to 400,000 motor-vehicle collisions per year in the United States. Considering that the National Highway Traffic Safety Administration (NHTSA) recorded 6,279,043 motor-vehicle accidents in 1999, sleepiness would account for 3.2 to 6.4% of the accidents that year. In comparison, NHTSA estimates that alcohol was involved in 7% of all crashes in 1999.

The practice of driving home after a night shift appears to be a significant occupational risk for health care workers. Steele (1996) reported the results of a survey of emergency medicine residents that found nearly 75% of the auto accidents and 80% of the near-crashes occurred following a night shift. That same year, Novak reported that approximately 95% of night nurses working 12–hour shifts reported having had an automobile accident or near-miss accident while driving home from night work.

Travel-Related Risks

How we choose to travel to work, during work, or for recreation predisposes each of us to additional risks. Travel-related deaths account for nearly half of all accidental deaths, with passenger cars and taxis having a significantly higher death rate than all other modes of travel (Figure 3-11).

There is a motor-vehicle death every 13 minutes. However, mile for mile, it is far riskier to walk or jog—if it involves crossing an intersection—than to use any form of motorized vehicle, including motorcycles. Pedestrian deaths, estimated at nearly 6,000 each year, are more than double the rate of motorcycle deaths.

Figure 3-11 depicts the death rates per 100,000,000 miles of travel for a three-year period for the major modes of transportation. From 1997-1999, scheduled airlines were the safest mode of transportation. Transit buses and school buses were next, but had ten times the death rate when compared to the airlines. Fatalities by automobile were about 22 times greater per passenger-mile than by city bus. In 22 years, HEMS has flown an estimated 3,002,176 hours, covering an estimated 360,261,121 miles (using an average of 120 miles-per-hour). Normalizing our HEMS data for 137 crewmember fatalities yields a death rate of 38.0 per 100,000,000 miles traveled.

How do you manage the risk of being involved in an auto accident? While automobile accidents kill a great many people, there are ways to manage the risk and reduce your chances of suffering a fatal auto injury. In motor-vehicle collisions, large cars are generally safer than small ones. You are roughly twice as likely to die in a serious auto accident if you are in a small car rather than a large car. Yet, for various reasons, many of us choose to drive small cars. Driving at night, mile for mile, is almost four times more likely to end in a fatal accident than driving during the daylight. Yet most people still drive at night. The lap-shoulder seat belt reduces fatalities in front-end collisions by 42%, but it is reported that 32% of Americans never wear seat belts. However, when you take into account car size and seat belt use, you are less likely to die in a large vehicl accident wearing no seat belt than in a small car wearing a seat belt.

Mode of Transportation	Death Rate
Buses	0.04
Railroad	0.06
Scheduled Airlines	0.004
Passenger Cars and Taxis	0.87
HEMS	**38.0**

Figure 3–11: Transportation Accident Death Rates / 100,000,000 miles, 1997 to 1999

Adapted in part from: National Safety Council, Injury Facts 2001 Edition

Helmets are an important consideration when it comes to bicycles and motorcycles. Helmets reduce the risk of fatal injury to motorcyclists by 30%. Helmets can also reduce the risk of serious head injury in bicycle accidents by more than 70%.

Ground Ambulance Accidents

Emergency vehicle accidents are not unique to air medical transport. A frequent discussion among transport professionals and other health care providers involves comparing the risk vs. benefit of ground vs. air transport. EMTALA guidelines require that the risks and benefits of all inter-facility transfers be explained to the patient. This should include an explanation of the anticipated risks and benefits of the chosen mode of travel—air or ground.

Unfortunately, the availability and accuracy of statistics regarding ground ambulance accidents is even worse than that of air medical transport. Similar to HEMS, no exposure data exists for ground ambulances. There is no information nationwide as to the number of miles traveled, number of ambulances or [illegible] number of patients transported. The [illegible] of this information makes it impossible to make a meaningful comparison between air and ground transport. However, some information is available regarding ambulance accidents.

The National Safety Council publishes data on crashes involving emergency vehicles in the United States. The NSC annual tabulations are based upon the Fatality Analysis Reporting System (FARS) and General Estimates System (GES) which are made available each year from the National Highway and Safety Administration. However, experts in the field of ground EMS transport question the accuracy of these statistics. There is no central tracking system to identify and capture ground ambulance accidents. Some accidents will be reported as "ground ambulance" accidents. In some systems, however, where EMS is a component of the Fire Department, the accident may be logged as having involved a "fire" vehicle. Some accident reports may list the vehicle as a "light [illegible]k." Some states track ground ambulances aggressively. In New York State alone, there are an average of 350 ambulance accidents each year, injuring an average of 2 people per day. However, many states do not have any system in place to track accidents accurately.

In April 2002, Robert Davis reported in *USA Today* that there might be an estimated 15,000 ambulance crashes a year. This estimate is approximately three times the number of ground ambulance accidents that we find in the NSC annual publications. Other sources suggest from sample data that it is very reasonable to estimate one fatal ambulance crash each week, as many as ten serious injuries every day and as many as 10,000 total injuries every year. Figure 3–12 presents three years of NSC data for ground ambulances, as well as other emergency vehicles (police and fire).

USA Today reported that with "relatively few fatalities each year (. . .out of millions of ambulance calls), federal officials say there is no pattern that triggers any alarms," and ". . . .there is not a huge safety problem."

There are obviously those who would disagree.

USA Today referenced a 1993 Houston study that found that ambulances were 13 times more likely to be involved in an accident than other vehicles based upon the number of accidents per miles driven. That study also determined that ambulances were five times more likely to be involved in an accident that resulted in injuries.

Our analysis of the NSC data for 1997–1999, found that ground ambulance had the highest percentage of fatal accidents when comparing each category of emergency vehicle. Over the 3-year period, 0.47% of all ground ambulance accidents resulted in a fatal injury. Fire vehicles were a little better at 0.39% and police were 0.32%. In addition, if you consider the number of total fatal injuries per 1,000 emergency vehicle accidents, the ambulance remains the most lethal. Over the 3-year period, the ambulance averaged 5.2 fatal injuries per 1,000 accidents, compared to 4.8 deaths for fire vehicles and 3.49 for police. The percentage of accidents that resulted in injuries is also the highest for ambulances (36%) compared to the fire (18%) and police (32%) vehicles.

From the 1997–1999 NSC data, in fatal, multi-vehicle ambulance accidents, only 25% of the deaths were occupants of the ambulance. Less than 3% of the fatalities were the ambulance "driver" according to the NSC data. Over 22% of those killed were "emergency vehicle passengers". The NSC tables did not differentiate between the patients, medical personnel, patient's family or others who were killed in the ambulance, making it impossible to know the total number of ground ambulance personnel killed in accidents. Of the remaining fatalities, two-thirds of those killed in these accidents were occupants of another vehicle and 8% of the fatalities were nonmotorists.

Recreational Risks

When it comes to sports and recreational activities, the National Safety Council and other publications make little if any effort to compare or rank the relative risk of injury or death. There are too many variables and unknowns to consider, including frequency and duration of exposure, number of participants and accurate numbers of injuries. The only injuries generally known are those that required emergency treatment. Most of the statistics come from emergency department logs.

The rising popularity of extreme sports was documented in the 1999 *Time* magazine article.

More Americans than ever are injuring themselves while pushing their personal recreational limits. BASE jumping (jumping from Buildings, Antennas, Span/bridges and Earth/cliffs) has one of the sporting world's highest fatality rates. In its 18-year history, 46 participants have been killed. Currently, there are more than a thousand jumpers in the U.S. and more getting into it every day. The sport has never been more popular.

While there has been a steady decline throughout the '90s in the participation in sports like baseball, touch football, and aerobics, there has been rapid growth in adventure

	Ambulance				Fire Truck/Car				Police Car			
	97	98	99	Avg.	97	98	99	Avg.	97	98	99	Avg.
EV in fatal MVA	28	25	15	0.47%	20	17	17	0.39%	97	83	65	0.32%
EV in injury MVA	1,465	2,306	1,473	36.4%	997	781	677	17.6%	8,305	8,210	8,645	32.4%
Total number of MVAs	4,745	4,615	5,050		3,928	3,188	6,839		23,725	24,417	29,419	
EV driver killed	0	2	0	2.7%	5	4	5	21.2%	19	17	17	19.6%
EV passengers killed	8	7	2	22.7%	3	3	3	34.8%	6	3	4	24.4%
OV occupants killed	21	18	11	66.7%	13	12	9	51.5%	54	66	40	59.0%
Nonmotorist killed	2	2	2	8.0%	4	3	2	13.6%	24	10	11	16.6%
Total Deaths	31	29	15		25	22	19		103	96	72	
al injuries	3,351	3,274	2,659		1,467	1,035	1,130		12,689	12,339	15,230	

Figure 3–12: Emergency Vehicles Involved in Motor Vehicle Accidents, 1997–1999 (EV=Emergency vehicle; OV=Other Vehicle)

Adapted from: Injury Facts: 1999 Edition, 2000 Edition, and 2001 Edition. National Safety Council.

sports. Snowboarding has grown 113% in five years and now boasts nearly 5.5 million participants. Mountain biking, skateboarding, scuba diving, and other more hazardous activities have seen more and more people participate. In 1997 the U.S. Consumer Products Safety Commission reported that 48,000 people were treated in hospital emergency rooms with skateboarding-related injuries—33% more than the previous year. Visits to the E.R. were also up for snowboarding injuries (up 31%) and mountain climbing (up 20%). The US Parachute Association reports that 10% of skydivers suffer injuries requiring medical attention. Annually, there are approximately 30 deaths, or 1.2 deaths per 100,000 jumps. In contrast, there have been only 20 serious injuries reported from an estimated 1,000,000 bungee jumps between 1988 to 1994. During the same time there were 7 deaths, for a death rate of 0.7 per 100,000 jumps.

Recreational Activity	Injury Rate
Skydiving	10%
Hockey	4.08%
Rugby	2.4%
Basketball	1.94%
Football	1.66%
Snowmobiling	1.34%
Bicycle Riding	1.21%
Baseball/Softball	1.07%
Skateboarding	0.76%
Roller/In-line Skating	0.41%

Figure 3–13 *Adapted: National Safety Council, Injury Facts 1999 Edition*

Some participation and injury statistics were available from the National Safety Council and other sources. While the accuracy of injury rates may not be precise for the reasons previously mentioned, some calculations are presented for comparison.

Any meaningful comparison between recreational injury rates and work-related injuries may be difficult. However, if you look at the "all industry" occupational injury rate of 2.86%, it would suggest that you are more likely to get injured on the job than participating in any of the above sports except hockey. On the other hand, looking at the injury rate for HEMS personnel of 0.16%, it would seem that you are less likely to get injured in a helicopter accident than participating in these sports.

SECTION 4: SAFETY AND RISK MANAGEMENT IN HEMS

No report on HEMS safety would be complete without trying to identify ways to enhance program (and industry) safety and reduce risk. While every air medical program has similar exposure characteristics, no two programs are exactly alike. This section will look at four basic requirements of a safety program, introduce some key aspects of risk management, and then highlight the benefits of a multidisciplinary approach to improve safety.

PRINCIPLES OF A SAFETY AND RISK MANAGEMENT PROGRAM

A safety and risk management program for an air medical program must encompass two aspects. Most important is doing everything possible to prevent an accident from occurring. If this fails and an accident does happen, everything must be in place to mitigate the impact of the accident.

Being safe does not eliminate risk—it reduces it. There are four basic principles that should guide the coordination, implementation, and evolution of a safety and risk management program for air medical operations. These principles are attitude, participation, education, and judgment.

Attitude

Safety does not just happen, it is not a specific event or a "thing"—it is an attitude. This perhaps is the most important component of the safety equation and may override all other aspects and variables. Everyone must have the right attitude about safety in order to participate and survive in an air medical transport program. This, along with a commitment to safety, is essential and must be exhibited by every crewmember and every manager. The attitudes should reflect the mission that safety *must* be the program's number one priority.

A number of obstacles may prevent the development of a sound safety program. An FAA Advisory Circular (AC) No. 60-22 defines attitude as "a personal motivational predisposition to respond to persons, situations, or events in a given manner that can, nevertheless, be changed or modified through training." Negative attitudes, however, are particularly difficult to overcome. Some people may think that safety is not their responsibility and their actions are not likely to impact the safety of flight or result in an accident. In some cases, identifying potential problems may seem to be too threatening to discuss and may simply be avoided. In other circumstances, denial occurs as team members insist that there is no safety problem.

Complacency is another serious problem and in many ways may represent a negative attitude. Merriam-Webster's Collegiate Dictionary defines complacency as "self-satisfaction accompanied by unawareness of actual dangers or deficiencies." Having learned things before or having done certain activities in the past may result in overconfidence and eventually to errors in performance. Never having an accident or incident does not assure continued safety if it results in complacent attitudes. It results in smart people sometimes doing dumb things. In 1901, Wilbur Wright wrote, "Carelessness and overconfidence are usually more dangerous than deliberately accepted risks." One hundred years later, this statement is still appropriate.

In 1997, the pilot of an Aerospatiale AS-365N Dauphin transported two passengers to a corporate ramp at Indianapolis International Airport. Upon shutting down the engines and applying the rotor brake, one passenger exited and walked forward of the helicopter and turned into the path of the rotor system. The passenger was struck in the left temple by a main-rotor blade and killed. In January 2001, a hospital security guard walked into the tail rotor of a Bell 206L as the helicopter was preparing to depart the base hospital helipad. The security guard died of his injuries. It may be very difficult to determine if complacency, carelessness, or overconfidence were contributing factors in these accidents.

Participation

A safety program must be planned, instituted and practiced every day and on every flight. It is not enough to assume that hospital administration, program management, the pilots, or the aviation operator will be completely respon e for safety. The safety program must be multidisciplinary and responsive in order to be successful. Safety is dynamic. Things change. Crewmembers (pilots, mechanics, medical and communications) come and go, aircraft may change (primary or backup), weather conditions vary, and a program may fly to hundreds of different locations. Every flight is different. It takes teamwork, where individuals interact effectively and efficiently with fellow crewmembers to maintain a safe aviation operation.

There is no such thing as a "free ride." Whatever the role of a team member in the program, each individual must acknowledge the critical fact that safety is their prime responsibility. It requires active participation, rather than passive observation. While medical personnel are not expected to be experts in aviation, each must be proficient with their safety-related responsibilities. At times, when delivery of medical care and safety may seem to come into conflict, safety t always take priority.

Each crewmember must recognize his/her role to help identify, address, and help resolve (as appropriate) potential safety concerns. Every situation represents an opportunity to learn and to improve. A program should encourage every member to identify opportunities for improvement, either to enhance program safety or efficiency.

Education

Education is a key ingredient in identifying, understanding, and actively managing risk. For a pilot and air medical crew, being knowledgeable of the elements that may increase or decrease the related risk should lead to taking appropriate steps to minimize unnecessary exposure. The result would be to greatly reduce the chance of being involved in an accident or incident.

There are many aspects of education that may be considered part of a safety program geared to actively manage risk. ation and training obviously begin n the pilots and mechanics and continue with the medical crew and communication specialists. It must also include the security and public safety personnel who set up and/or secure landing zones or helipads.

Another important aspect of education is learning from past mistakes. In separate documents, both the Aircraft Owners and Pilots Association (AOPA) Air Safety Foundation and the Flight Safety Foundation support the belief that pilots can learn valuable lessons from analyses of past accidents and incidents. Accident data often yield clues to safer operations, and can be applied at relatively little cost and with no additional regulations. By analyzing mishaps, pilots, medical teams, and program administrators can learn about potential risks and take proactive steps to control them. The U.S. Air Force *Guide to Mishap Investigation* states, "the proper use of mishap experience is reducing mishap potential."

It is important to realize that education isn't everything —it is merely the beginning. Being able to apply the knowledge under routine and emergency conditions is expected of each and every crewmember. Each crewmember must be able to perform his or her safety-related functions proficiently and independently. It is an unnecessary distraction and risk for pilots and medical crewmembers to worry about someone else who does not do his/her job.

Judgment

FAA AC No. 60–22 defines judgment as "the mental process of recognizing and analyzing all pertinent information in a particular situation, a rational evaluation of alternative actions in response to it, and a timely decision on which action to take." In 1986, Arthur Negrette authored an article entitled "Spatial Orientation: It Plays No Favorites." He reported that on the average, it takes a helicopter pilot five seconds to recognize a hazard, determine the necessary corrective action, and respond.

Some people feel that good judgment is an inherent characteristic and not one that can be easily taught. Someone may be given the tools through education and months or even years of experience, but may still lack the ability to put it all together for optimal performance and outcome.

The AC goes on to define the Poor Judgment (PJ) Chain as "a series of mistakes that may lead to an accident or incident." The AC states that there are two basic principles that are generally associated with the creation of a PJ chain: (1) one bad decision often leads to another; and (2) as a string of bad decisions grow, it reduces the number of subsequent alternatives for continued safe flight.

In the HEMS environment with its limited resources (generally one pilot and two medical crewmembers), it is essential for each and every crewmember to be at the top of their game, using sound judgment to recognize individual limitations and changing conditions. Having alternate plans and knowing when to implement them can impact both aviation and medical safety. For example, in aviation, judgment is key when it comes to the decision to initiate a flight or when to abort a flight. In medicine, it may be exemplified in your management of the patient with a difficult airway. What drugs, if any, should be considered? What is the backup plan if the intubation is not successful? Having the knowledge and the skill is essential. Sound judgment and proficiency are more likely to yield a positive outcome. In HEMS this will enhance overall safety.

RISK MANAGEMENT

Risk management is a discipline for dealing with uncertainty; a science of looking to the future through today's vision. It enables us to make a range of informed decisions about our environment, health, safety, and our social and economic well being. It is about managing resources wisely, protecting from harm, and safeguarding assets. In HEMS, risk management should be directed toward optimal flight safety as well as providing the highest quality of medical care.

Effective risk management acknowledges and identifies threats, evaluates and prioritizes the risks, considers the probability a risk will materialize, and controls loss (preventing loss and reducing the severity should a loss occur). Results must be evaluated and strategies revised as appropriate. With this information, a person or organization is able to make an informed decision as to how they will deal with various risks.

Identifying Risks

In this report, we have already identified many of the issues that could represent threats to the safety of flight. In the reports from the Air Medical Accident Analysis and the Helicopter Accident Analysis Team specific problems that have led to accidents are identified.

Additional information is obtained from the *AirMed* "2000 Aircrew Survey" that identified the situations that HEMS pilots felt posed the greatest threats (i.e., greatest risk) to flight safety. Scene operations (64%), program complacency (44%), and mission-related stress (35%) were the three most common concerns. Figure 4–1 shows the various risks that were identified.

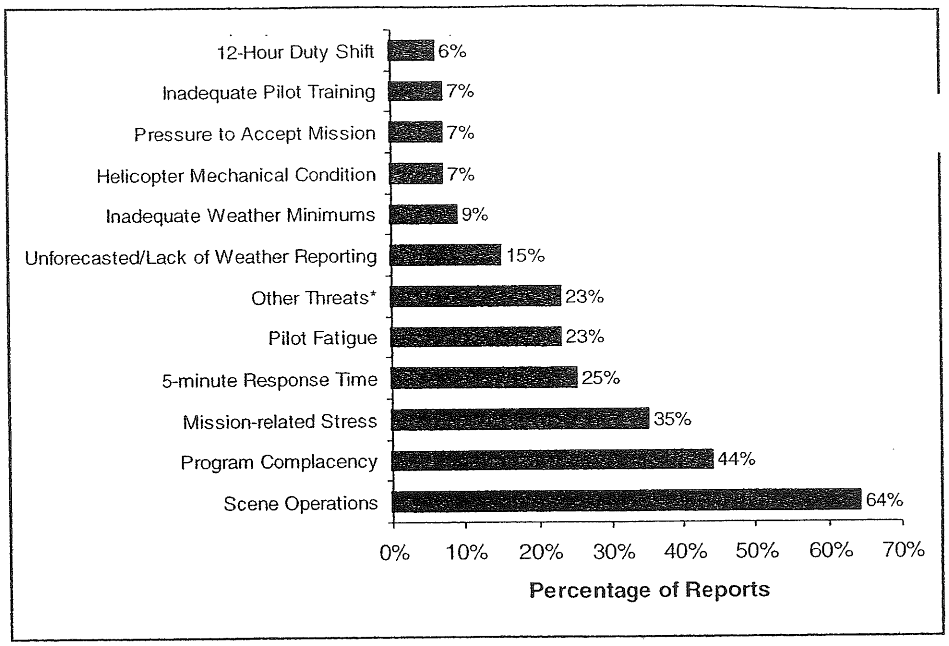


Figure 4–1: Greatest Threats to Flight Safety (n=148)

"Other threats" included night operation, general aviation traffic and negotiating geography/mountainous terrain and others. *Adapted from: Rau, 2000 Aircrew Survey, AirMed, Nov/Dec, 2000*

A more comprehensive "EMS Line Pilot Survey" was conducted by NEMSPA and HAI in 2000–2001, which yielded a combined total of 304 responses. In general, there were considerably more variables to choose from in this survey, which often resulted in lower percentages for each specific response.

The greatest risk to safety industry-wide was found to be management or crew pressure (11%). Inexperience was next (9%), followed by LZ operations/hazards and weather reporting/forecasting at 8% each. At 7% were poor decision-making, night operations, and marginal VFR/inadvertent IFR conditions. When asked what risk factors contributed to accidents in recent years, the most common response was pushing weather minimums (14%), followed by complacency (11%), pilot complacency (10%), inexperience (8%), and lack of IFR training (8%).

There were a number of questions in the "EMS Line Pilot Survey" that further clarified the types of pressure the pilots identified, as seen in Figure 4–2.

Survey Variable	Response
Undue pressure from:	
Program Management	32%
Flight crews	14%
Operator	13%
Dispatch	13%
Pressure from:	
Crew/management to speed up response or lift-off times	55%
Other pilots (indirectly) to launch/continue in marginal weather	13%
Crew/management to launch/continue in marginal weather	8%
Pilots pressure themselves to:	
Launch/continue in marginal conditions	13%
Fly when fatigued or ill	32%
Speed up response or lift-off times	48%

Figure 4–2: Pilot-related Pressures (n = 304)

Adapted from: EMS Line Pilot Survey, NEMSPA and HAI, 2001

Dealing with Risks

Techniques to Control Risk

There are six techniques to control risk. The first and most common option is *risk avoidance*. If it is not worth assuming the risk, avoiding the exposure may eliminate the risk. In air medical transport, an alternative would be ground transport, which has its own inherent risks. A program could also decide that scene accidents or flying at night pose too great a threat and elect to avoid these situations.

The second option is *risk prevention*. In this situation, the HEMS program would take the necessary action to try to prevent a loss through comprehensive training (pilots, medical crews and communicators), policies and procedures, and so on. A helicopter program may choose to do scene flights only during the day or only land at pre-designated landing zones. A program may also conclude that a twin-engine aircraft is less likely to have a potentially catastrophic malfunction (i.e., engine failure of a single-engine helicopter) or that two pilots will reduce the likelihood of pilot error. All of these options strive to decrease the possibility of an aircraft accident, but do not eliminate all possibility of that loss.

The third technique is *loss reduction*, which is an attempt to reduce the severity of the loss. The decision to wear helmets or nomex are forms of loss reduction in HEMS. Survival training and appropriate survival gear may also reduce the losses in an accident, but do nothing to prevent an accident from occuring.

Segregation of risk is the next alternative. While the technique has similar aracteristics to loss reduction, it also very distinct features. A program may choose to have separate helipads for their multi-helicopter program or for a visiting aircraft to use. If a helipad accident were to occur, only one helicopter would be involved. Some families use this technique to control the risk of travel on commercial airlines. Rather than all flying together on one airplane, the family will split up, taking two different flights, reducing the risk of an accident taking an entire family.

The next alternative is *risk transfer*, when someone else assumes the risk. In HEMS, this could include not having a flight program or having another flight program undertake your transports (similar to risk avoidance). It may also be a factor in considering who is responsible for the various aspects of the Part 135 aviation operation; who is responsible for the training of the pilots and mechanics; or who is responsible for the maintenance of the aircraft and compliance with all Federal Aviation Regulations. It could be the pital or flight program, or this could be ansferred to a full-time aviation operator. Risk transfer can also be represented by the various hull, liability, disability, and life insurance policies that are in place to address various losses. Power-by-hour is yet another form of risk transfer.

Risk retention is the final option, where a program or individual consciously assumes the risk, taking no specific steps to reduce the risk or the severity of a loss.

HEMS-Specific Risks

Dozens of intervention strategies have been recommended in the Air Medical Accident Analysis and the HAAT report. It is appropriate to highlight specific HEMS risks and several considerations to deal with these risks.

Scene Operations. The concern over scene operations, as identified in Figure 4–1, is long standing and justified—especially at night. Potential landing zone (LZ) hazards (trees, wires, etc.) represent gnificant threat to safety. To improve ety, 9% of the responses to the "EMS Line Pilot Survey" favored night vision goggles.

Education plays an important role in scene safety. Educating pre-hospital personnel on the selection and preparation of the LZ is key. Educating the medical crew and their active participation to look for hazards on approach and landing is also essential. However, as the statistics showed, very few of the accidents that occurred on "scene" flights occurred while landing at the scene. More accidents occurred with the patient on board than on any other leg of the scene missions.

Complacency. Program complacency has already been addressed. It is important for pilots, crewmembers, communication specialists and administrators to recognize that complacency may be the greatest danger in HEMS—the silent killer. The complacent individual generally exhibits a low level of awareness and does not recognize the need for action or involvement. This leads to mistakes.

Someone once was asked, "What is the difference between ignorance and complacency?" he responded, "I don't know and I don't care."

Pressure and Stress. Mission-related stress has also been addressed, in part, with regard to both self-imposed and externally imposed pressure. In 1988, the NTSB report recognized both of these pressures as significant concerns. Thirteen years later, the "EMS Line Pilot Survey" identified management or crew pressure as the greatest risk to safety industry-wide. Have we made no progress over the past decade?

Weather. It is of interest that two factors that scored fairly low in Figure 4–1 were pilot training (7%) and unforecasted/lack of weather reporting (15%). In the *AirMed* pilots' survey, 85% of the pilots reported having made a forced landing once or twice in their HEMS career for deteriorating weather conditions. A responding 32% reported at least one forced or precautionary landing during the past year due to weather. This would seem to imply that the pilot's ability to identify and actively manage a risk diminishes the perception of a particular threat to safety. On the other hand, concerns that they may have little direct control over (i.e., scene LZs, program complacency, etc.) remain significant threats.

Weather, however, remains an all too common factor in HEMS accidents. Despite thorough planning and adherence to weather minimums, it is possible for any HEMS pilot to encounter unanticipated weather and enter inadvertent instrument meteorlogical conditions (IMC). The first line of defense for any pilot against inadvertent IMC is to take the necessary steps to avoid the situation. Comprehensive weather planning is perhaps the most important step. This should include access to updated weather forecasts and a working knowledge of weather charts and reports, as well as familiarity with local weather trends. Forecasts are not guarantees but forecasts for marginal conditions are usually accurate. It is only a short step from marginal conditions to unflyable conditions. A marginal forecast and wishful thinking that "the weather won't be as bad as they say" has no place in aviation, especially air medical transport.

The pilot's actions immediately after encountering IMC will determine the outcome of the flight. In many weather accidents the pilot waited just a little too long to change his mind. In a significant number, deciding to divert only a few minutes earlier would have kept the flight out of danger. Trained and proficient pilots, who have a plan of action in the event of inadvertent IMC, are more likely to experience a successful outcome. Another important defense against inadvertent IMC is a willingness to land the aircraft. Such willingness runs counter to the pressures HEMS pilots sometimes feel to complete their missions.

Although it is impossible to make a direct correlation, more experience in weather-related decision making should result in a gradual reduction in some of the VFR into IMC accidents and incidents.

Night and Spatial Disorientation. Flying at night poses its own unique risks in aviation. This is especially true in HEMS. The FAA manual, *Aeronautical Decision Making for Air Ambulance Helicopter Pilots*, notes that "even on the clearest night with VFR (visual flight rules) conditions, a pilot can come close to IFR (instrument flight rules, i.e., inadvertent IMC) operations if there is no moon and/or no ground lights to establish a horizon reference." In contrast, there could be an abundance of ground lights below and stars above that can seem to merge into a continuous sweep of pinpoints that can deprive a pilot of any horizon reference. In both situations, with the loss of the visual reference (the ground and/or horizon), the interpretation of motion and position in relation to the environment may be lost. An inexperienced pilot who becomes disoriented, or who does not trust his/her instruments, may change direction, altitude, speed, etc., and if unable to compensate is likely to have an accident.

Another risk lurking in the night sky is the unseen cloud. Clouds disappear easily in the dark and a pilot can fly into one without seeing it coming. In all of these nighttime situations, instrument training and proficiency may help mitigate the potential risk.

FAA Advisory Circular 60–4A (February, 1983) addresses pilot's spatial disorientation. In this AC, it states: "Tests conducted with qualified instrument pilots indicate that it can take as much as 35 seconds to establish full control by instruments after the loss of visual reference with the surface." While the tests were performed on fixed-wing aircraft, the results may be more dramatic with helicopters since they require even more pilot intervention to maintain control.

Another group of fixed-wing pilots were asked to identify their personal experience with spatial disorientation. The most common sensory illusions reported were:

- A sensation that one wing was low although wings were level (60%)
- On leveling after banking, a tendency to bank in opposite direction (45%)
- When in a turn, a feeling as if they were straight and level (39%)
- Becoming confused in attempting to mix "contact" and instrument cues (34%)
- On recovery from a steep climbing turn, the feeling of turning in the opposite direction (29%)

This AC also points out that while visibility may be above VFR minimum, the natural horizon and surface references may at times become obscured in low-visibility conditions, on over-water flights, and at night—especially in sparsely populated areas. The AC concludes "You and only you have full knowledge of your limitations. Know these limitations and be guided by them."

Pilot Training and Experience. This leads directly into the issue of pilot training and experience. In the *AirMed* survey, pilot training scored very low as a perceived risk to flight safety.

In the HAI/NEMSPA survey, however, when asked "what can be done to improve industry safety," the most common response was to improve the quality and frequency of training (17%).

The Frazer articles and Hart lectures have concluded that in the vast majority of HEMS accidents, this did not appear to be a major factor. This report is not about to address specific training requirements for the aviation (pilots and mechanics) professionals. However, a study by FlightSafety International (FSI) seems worthy of mention.

FlightSafety offers flight simulator training for both fixed-wing and rotor-wing pilots. Their full-motion simulators can reproduce various in-flight emergencies during various lighting and weather conditions. FSI conducted a study to determine the impact that simulator training had on the fixed-wing fatal accident rate. FSI estimates that they trained approximately 20% of the fixed-wing pilot population. Looking at five years of accident data, they identified a total of 471 accidents, or an average of 94 per year. They postulated that if simulator training made *no* difference, the FlightSafety trained pilots should have accounted for approximately 20% (92) of the total accidents. Instead, the FSI-trained pilots had only 3% (15) of the total accidents. The expected accident frequency was reduced by more than 80%. FlightSafety concluded that: "The benefits of simulator training are obvious. ...and the safety record proves it."

While simulator training may indeed be beneficial, other considerations may also be factors. It is also possible that the companies that went to the effort and expense of sending their pilots to simulator training are more safety-proactive in other areas as well.

Of interest, the *Air Medical Accident Analysis* rated full-motion simulators as highly effective, but low feasibility. Perhaps more interesting is the reponse to the "EMS Line Pilot Survey" when asked "what can be done to improve industry safety?" Of the 304 responses, only one selected "simulation."

AIR MEDICAL RESOURCE MANAGEMENT

Air Medical Resource Management (AMRM) is not a unique concept. Based upon more than 20 years of business and aviation models, AMRM is specifically designed for our industry. The goal is to provide the methodology to make optimum use of the capabilities of the individuals and aircraft systems to achieve the safest and most efficient completion of a flight.

In 1979, NASA suggested that business managerial concepts could be applied in the cockpit to reduce the high number of "human-factors" accidents occurring with the airlines. Within 10 years, *Cockpit Resource Management*—later expanded conceptually to *Crew Resource Management* (CRM)—was included in training worldwide at most major airlines. The U.S. Air Force had begun full-scale CRM training of all crews of multiperson aircraft. Today, there is sufficient evidence that CRM training and practice have improved aviation safety.

CRM is the effective *management* of all resources available to ensure that all group members are operating from a common frame of reference and toward a common goal of aviation safety. CRM provides a framework for accomplishing a given mission. In air medical transport, training programs have been and are being developed that teach CRM skills and principles not only to pilots, but also to medical personnel, communication specialists, maintenance personnel and management. In fact, at the 2000 Air Medical Safety Summit, the number one priority identified by the industry leaders (aviation, medical and management) was CRM and related training. At an all-day seminar prior to the Air Medical Transport Conference in September 2001, a new *Air Medical Resource Management* Train-the-Trainer course was presented for the first time.

The FAA's Advisory Circular identifies components of CRM to include teamwork, communication skills, decision making, workload management, situational awareness, preparation and planning, cockpit distractions, and stress management.

Teamwork is key in AMRM and must be maximized to facilitate the transfer of information. In HEMS, teamwork must include everyone who could impact the safety of flight, including the pilots, medical personnel, communication specialists, maintenance personnel, air traffic controllers (ATC), and management. Much like a sports team, each person must know his/her role, be an active participant and be able to execute his/her assignment when called upon. In sports, the goal is winning. In aviation, "winning" is a safe and efficient aviation operation resulting in the safe return of the aircraft and crew at the conclusion of each and every flight.

Effective communication skills are essential in developing teamwork. Pilots can increase the probability of a safe flight by overcoming barriers in communication and learning to effectively seek and evaluate information. Communication problems are often cited as a causal factor in aircraft accidents and incidents. At a recent air medical conference, a leading safety expert in HEMS stated, "open and effective communication might have prevented perhaps as many as 80% of EMS accidents."

Aeronautical Decision Making (ADM) refers to a systematic mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances. ADM includes risk assessment and stress management. It also illustrates how personal attitudes can influence decision making and how those attitudes can be modified to enhance safety in the cockpit. Good decision making skills are not necessarily inherent and must be learned. A pilot must seek and evaluate all relevant information, using all available resources, before making an important decision. These resources may include people (medical crewmembers, ATC, communication specialists, other pilots) aircraft ruments, documentation (flight manuals, checklists, etc.), and sensations (vibrations, sights, smells, position).

Studies by a number of researchers have shown that there is a strong correlation between errors in decision making and the severity of accidents. While many skill-related problems may result in minor injuries and damage, faulty decision making processes often result in accidents with serious injuries and fatalities.

Situational Awareness is the accurate perception and understanding of all the factors and conditions going on around you. In aviation, this deals with the four fundamental risk elements that affect safety before, during, and after the flight —the pilot, the aircraft, the environment, and the type of operation that comprise any given aviation situation. This requires a pilot's full attention. Here too, cockpit distractions must be kept to a minimum. The Aviation Safety Reporting System (ASRS) identified pilot distraction as one of the most frequent causes cited in the reported incidents.

Managing the workload is critical to the single-pilot operation. Tasks must be carefully prioritized and the pilot must avoid being distracted from his/her primary duty of flying the aircraft. The single pilot can often benefit by utilizing his/her resources and sharing tasks. This could include having the medical crew handle some of the communications with dispatch or EMS ground personnel, looking for hazards while landing or taking off, requesting assistance or information from ATC or from dispatch, and prudently using automation such as an autopilot.

In the single-pilot HEMS operation, preflight planning and preparation is of special importance. Generally, no one else is available to confirm radio frequencies and make radio calls, fix positions and call out checklists. In a high-workload or stressful situation, the pilot must be able to call upon his/her training and items that may have been committed to memory, such as frequencies and emergency procedures, that otherwise might be difficult to confirm in an emergency. In addition, as appropriate, the pilot should utilize the other resources that may be available.

The effects of stress are often difficult to recognize and the inability to recognize this may be hazardous in aviation. Failure to manage stress often leads to eroded judgment, errors in decision making, decreased work performance, inattention, degraded communication skills, preoccupation, and complacency. A pilot suffering from stress may forget or skip procedural steps, accept lower performance standards, and exhibit a tendency toward spatial disorientation and misperceptions. These misperceptions may result in misreading maps, charts and checklists, misjudgment of distance and altitude, and loss of time perception. In a study of more than 700 naval aviators who had been involved in major aircraft mishaps over a four-year period, it was discovered that those pilots who exhibited the symptoms of inadequate stress coping were more likely to be involved in an aircraft mishap.

As you can see, the elements of AMRM are intertwined and do not stand alone. Together, they can be used to improve work performance and the safety margin in air medical transport. But crew resource management is not restricted to the aircraft. It can also be an essential learning tool for people who work together in any environment, including the emergency department or trauma room.

The Air Medical Accident Analysis recommended CRM training as highly effective and moderately feasible. The HAI/NEMSPA survey seemed to agree. Of the responses, 63% of the pilots surveyed found CRM effective in making the program safer and 41% found that CRM made the program more efficient. Unfortunately, the pilot survey also shows that we have several hurdles before us. A total of 38% of the respondents found CRM to be ineffective because it "doesn't work here" (3%), was not well presented (8%) or due to a lack of support from the program (6%), operator (3%), flight crew (9%) and some of the pilots (10%). The lack of support by some of the pilots is not surprising, as CRM proposes a way of doing things that is contrary to the way many pilots have trained and flown for years. Historically, pilot training leaves the pilot-in-command (PIC) as the sole arbitrator as to how to conduct a flight With AMRM, the PIC is still fully responsible but is encouraged to involve others who may be in a position to contribute to the decision–making process on behalf of safety.

SECTION 5: CONCLUSION

Every occupation has inherent risks. Medical professionals and transportation professionals are no different and are exposed to various risks every day. Transport Medicine combines these two fields into a unique medical specialty where the aviation and medical professionals face uncommon challenges and risks every day.

The risk of a helicopter accident is very real in HEMS. Since 1972, it is estimated that HEMS has flown an estimated 3.0 million hours while transporting approximately 2.75 million patients. In 31 years (through September 2002) there have been 162 accidents involving dedicated medical helicopters and four accidents involving dual-purpose helicopters in the United States. In 67 fatal accidents, 183 people have lost their lives, including 144 crewmembers. In the early and mid-1980s, during the HEMS industry's most rapid growth, we experienced an alarming number of accidents. The early and mid-1990s showed improvement, but 1998 to 2001 again showed an increase in the number of HEMS accidents across the nation. Despite this recent increase, however, the percentage of fatal accidents has declined by more than a third compared to the early 1980s. The fact remains, however, that since 1990, there has been an average of 2.5 fatal accidents annually, taking the lives of 5 to 6 crewmembers each year.

It must be pointed out that for all of the data that has been reviewed and analyzed in this report, many of our numbers are very small. To draw conclusions over a five-year or 20-year period may be somewhat reasonable. However, many of our calculations are greatly distorted due to the small numbers for year-to-year comparisons. Due to a low occurrence rate, aircraft accidents are poor indicators of safety trends. In addition, there may be limited first-hand information available as to the real cause of an accident if the accident resulted in fatalities.

There is no typical HEMS accident. However, several observations are noted. A disproportionate number of HEMS accidents occurred during night operations, during the cruise phase of flight, and on scene transports. Pilot error was attributed as the direct or indirect cause of HEMS accidents approximately three times more often than mechanical failure. Of the pilot errors, one-third were weather related.

In 1988, the NTSB concluded that poor weather poses the greatest single hazard to EMS helicopter operations. More than a decade later, deteriorating weather conditions continue to represent a significant risk in HEMS. In general, the cause of the weather-related accidents does not appear to be a pilot's disregard for established weather minimums at takeoff. Instead, it is the pilot's encounter with instrument meteorological conditions en route. In general, weather may not cause the accident, but it may increase the likelihood that an accident will happen.

Weather is the second most common factor or cause of HEMS accidents. Of the weather-related HEMS accidents, over 85% occurred at night. Approximately 75% of all weather-related HEMS accidents resulted in fatalities. The correlation between weather-related accidents and cruise flight is very strong. Degrading weather conditions can significantly compromise a pilot's ability to see and avoid obstacles—especially while at cruise speed.

Pilot fatigue and total hours of flight time do not appear to be significant factors in HEMS accidents. Looking at HEMS incidents, however, suggests that IFR rating and currency may be very helpful, if not invaluable, to overcome a situation and avoid an accident. In addition, communication problems, time pressures, and distractions are frequently identified as contributing risk factors in HEMS incidents.

The magnitude of injuries and aircraft damage are significant considerations in HEMS accidents. HEMS accidents are more likely to result in fatalities or serious injuries than other helicopter accidents. While pre- and post-impact fires occur in only a small percentage of HEMS accidents, nearly half of all the accidents result in the destruction of the helicopter. No conclusions, however, can be made regarding single- vs. twin-engine aircraft.

Our HEMS accident rates and fatality rates are based upon estimated exposure data. Data for the past fourteen years has been determined through several industry-wide surveys and various calculations. It is possible that our survey results have underestimated the number of HEMS programs and dedicated helicopters by ten percent or more. Therefore, our proposed exposure data may also be underestimated. As a result, our calculated accident and fatality rates could be overstated by an estimated ten percent. This difference, however, does not impact the overall trends identified in HEMS accidents nor our comparison with other aviation operations.

In the early and mid-1980s, the accident rate for HEMS was dramatically higher than all other aviation operations. Since 1987, however, we have seen a significant decrease in the HEMS accident rate to approximately one-third of what we experienced in the early to mid-1980s. The HEMS accident rate has remained consistently below the accident rates for both general aviation and all helicopter operations since the late 1980s. The fatality rate has also seen significant improvement since the late '80s. Despite a recent increase, the fatal accident rate is reduced by approximately 75% compared to the early 1980s.

Finally, comparing the HEMS risks to other occupations is very difficult due to the relatively small size of the "population" at risk. Looking strictly at the numbers, HEMS appears to have a significantly higher death rate than other occupations or causes of accidental death. Only heart disease and cancer have a higher fatality rate when compared to the 22-year average fatality rate for HEMS.

HEMS accidents are not caused by a single event, but by a chain of events. In most accidents, numerous risk factors can be identified. Acting on any of these risks and breaking the chain at any point may prevent an accident from occurring. The United States Aircraft Insurance Group (USAIG) has concluded that complacency is a factor in over 50% of all helicopter accidents. No one can afford to take a passive role in HEMS. The safety of flight requires the right attitude and active participation. Every pilot, mechanic, medical crewmember, communication specialist, and administrator must be fully knowledgeable of their role and responsibilities. Each must be committed to a safe operation and to ongoing risk management. To fly safe, a ogram must fly smart. Nothing takes e place of comprehensive training, proficiency, and sound judgment. An important training component should be Air Medical Resource Management. The goal of AMRM is to improve crew communications and interactions by addressing teamwork, communication skills, decision making, workload management, situational awareness, preparation and planning, cockpit distractions, and stress management. The focus of the team must be on doing "what is right" rather than on "who is right."

The risks in HEMS cannot be underestimated. In addition, the cumulative effects of multiple risk factors must be considered when making decisions on each and every transport. Risk management is a major component of the decision-making process. It relies on situational awareness, problem recognition, and exercising good judgment to reduce risks associated with each flight.

In the Forum section of the September/October 2001 *Air Medical Journal*, Ed MacDonald, the President of NEMSPA wrote about "the next accident". This article should be required reading for everyone in HEMS. It addresses the "it can't happen here" mentality and suggests why *it can happen to you*.

Tragically, there will be a next accident and more of our colleagues will lose their lives. Maybe not today, maybe not this month, or even this year. Hopefully, not for a long, long time. No one expects it and everyone assumes the next accident will involve someone else's program.

No one can eliminate the risks related to HEMS. Some may choose to avoid the risk. Programs may close and individuals may decide to pursue a different occupation. Others may choose to influence risk. Organizational culture can influence risk as much as any/all other factors. The cultures, in this case, represent the collective beliefs that shape behavior toward safety and a safe HEMS program. Working together, every member of a flight program must play a role to actively manage risk and to avoid taking unnecessary risk. Your safety demands it. Lives depend upon it.

Do whatever it takes. Don't be the next accident!

Acknowledgements

Nearly two years ago, the UCAN Safety Committee undertook a simple task to review a few articles pertaining to air medical accidents. Our Section Chief of Emergency Medicine, Dr. James Walter had challenged us for answers regarding the magnitude of risk in HEMS. Did we as a Safety Committee, flight program, or industry have enough information to fully appreciate the safety concerns and risks encountered every day? We decided to meet his challenge head on. Within a short time, this safety report took on a life of its own and our investigation and research were underway.

There are a great many people who participated and helped complete this project. My thanks to the entire UCAN Safety Committee for their dedication to this study and for enduring the endless revisions, additions, and various deadlines. I am also grateful to the entire UCAN crew and the Emergency Medicine faculty who encouraged us as we worked through the various phases of the project. Numerous individuals, operators and aircraft manufacturers shared database information that made our calculations possible. Without the endorsement of the AMPA Board of Directors and Pat Petersen, this report would never have been published in this format and in its entirety. The immediate response and support from Madeleine Byers (CJ Systems) and Sandy Kinkade (Bell Helicopter) further strengthened our resolve to pursue this publication and to obtain the necessary funding to make this document available to the entire air medical community.

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And finally, to Jane, Maddy and Jake. Thank you for putting up with the long hours needed to complete this project. Now, more than ever, I appreciate and understand the importance of putting "safety above all"—for myself, for my crew, for my colleagues. For my family.

—*Ira Blumen*

Attachment 1:
HEMS Accident Summary, 1998-2002

Date Time	Aircraft N Number	Program	City State	Mission Type	Mission Phase	Phase of flight	Pt	Injuries	Day / Night	Weather	Fire	Aircraft Status	Operator	Comments / Description / NTSB Probable Cause(s)
1/11/98 @ 2250	222UT N222UH	AIRMED	Salt Lake City, UT	ONS	POB	CRU	1	4F	Night	Snow, wind >35mph	PIF	Destroyed	Air Methods	Storm front moving in, wind gusts exceeding 35 mph. Fatalities:3 crewmembers and 1 patient. **NTSB Final: Pilot Error.**
3/23/98 @ 0740	205A-1 N90230	Los Angeles City Fir Air Ops Unit 8060	Los Angeles, CA	ONS	POB	TKF	1	4F, 2S	Day	Clear, calm winds 20 mile vis.	Unk	Destroyed	Public	Enroute to MVA and during transport to LA Children's Hospital, pilot reported inflight emergency. Fatalities: 3 crew,1 patient. **NTSB Preliminary:** Separation of tail rotor blades and 90-degree gearbox during cruise flight
5/24/98 @ 1235	206 L-3 N27AE	Air Evac EMS	West Plains, MO	INT	PGT	TKF	0	3S	Day	Clear	No	Destroyed	Air Evac EMS	Aircraft lost power during take off at ~ 60 ft altitude and low air speed. Hard landing into parking lot, main rotor blade struck light pole and aircraft rolled onto its right side. **NTSB Final: Improper maintenance.** Engine's accessory gearbox was improperly assembled, reducing oil flow to the turbine shafting, leading to a total loss of engine power.
6/5/98 @ 0549	350BA N911VA	Valley Air Care	Harlingen, TX	ONS	PGT	CRU	0	3F	Night	5 miles, broken ceiling at 1,400 ft; Grnd fog	PIF	Destroyed	Tex-Air	En route to a rural scene, the helicopter crashed 19 miles past the accident site. Impacted trees and terrain. Visibility severely restricted by thick smoke from fires in Mexico. **NTSB Final: Pilot error.** Continued flight into adverse weather conditions resulting in a loss of control due to spatial disorientation.
7/29/98 @ 2248	222B N911RA	SkyLife of Central CA	Fresno, CA	ONS	PGT	LNG	0	3N	Night	Not a factor	No	Significant	Rogers Helicopter	While landing at scene of accident, encountered significant blowing dirt and dust ~ 5 ft from ground, resulting in loss of ground reference. Helicopter rolled to its left, landing on its top. Crew was extricated with assistance, but was uninjured. **NTSB Final: Pilot error.**
8/20/98 @ 2114	222 SP N30SV	Intensive Air	Sioux Falls, SD	INT	PGT	CRU	0	3F	Night	VMC 10 miles; 8,500 ft overcast; winds 12 knots, to 26 gust	PIF	Destroyed	RMH	Enroute to pick up a patient. Routine radio contacts up to 5 min out. At ~2125, comm center received a call from Spencer Hospital informing them that the helicopterhad not arrived. **NTSB Final: Mechanical failure.** In-flight break-up traveling at about 130 knots at 960 ft above the ground. A fatigue crack of the swashplate outer ring pin of the main rotor assembly resulted in the separation of the pin, and ultimately the in-flight breakup.
8/28/98 @ 1053	BK-117 N230H	Topeka Lifestar	Topeka, KS	MAT		LNG	0	3N	Day	Not a factor	No	Significant	St. Louis Helicopters	Returning from 2 days of maintenance at an altitude of 300-400 ft, pilot heard a "loud bang" followed by the aircraft rotating to the right. Pilot was able to touch down upright then the aircraft rolled onto its left side. NOT COUNTED IN TOTALS. **NTSB Final: Pilot error.** Pilot failed to assure the engine cowling was secured, resulting in the cowling separating from the helicopter and damaging the main rotor and tail rotor.
11/29/98 @ 1756	MD-900 N977LF	LifeFlight	Boise, ID	ONS	POB	TKF	1	4N	Dusk to Dark	Over-Cast 10mi vis	No	No Wind-screen and main rotor blades	Idaho Helicopters	Departing from MVA in a remote canyon, aircraft stuck and severed unmarked power lines 150 ft above the ground. Pilot then determined that the helicopter was controllable and displayed no unusual flight characteristics, and chose to proceed to his destination. Aircraft completed mission and landed uneventfully at hospital with patient and crew. Post-flight examination revealed crazing of the windscreen and damage to 4 of the 5 main rotor blades requiring major repair/replacement. **NTSB Final: Pilot error.**

Date Time	Aircraft N Number	Program	City, State	Mission		Phase of flight	Pt	Injuries	Day / Night	Weather	Fire	Aircraft Status	Operator	Comments / Description / NTSB Probable Cause(s)
				Type	Phase									
12/13/98 @ 1745	AS 350-BA N911MV	Shannon Medivac One	San Antonio, TX	MAT		HOV	0	2N		Clear		Substantial	Southwest Helicopters	Instructor pilot (PIC) had been doing a 3-hr check ride with new pilot, with last maneuver "hydraulics off". PIC then initiated a normal takeoff (with hydraulics 'ON') and during the takeoff, the helicopter rolled over to the left. PIC reported it felt like a complete hydraulics failure. Rotor blades struck the ground, knocking tail nearly off, front of the aircraft was destroyed. **NTSB Final: Undetermined.**
2/12/99 @ 1720	AS 355 N355MF	LifeFlight	Toledo, OH	INT	PRF	LNG	0	3S	Night	IMC – Scattered snow squalls.	No	Destroyed	CJI	Flight aborted twice due to weather enroute to referring hospital. Pilot attempted a precautionary landing in decreased visibility. Aircraft struck tree and house 1.5 miles from hospital. **NTSB Final: Pilot error.** Inadvertent flight into IMC, subsequent spatial disorientation and loss of control; also inaccurate weather forecast.
2/13/99 @ 1645	BK-117 B-1 N220H	Hermann Life Flight	Houston, TX	ONS	POB	CLB	2	5N	Day	Clear	No	Substantial	Own Part 135	2-helicopter scene. During approach for landing approach, the pilot noticed power lines running parallel to the road but did not consider them to be a hazard. On take-off, the helicopter hit the power lines and the pilot landed the helicopter in an adjacent field. Undersides of the main rotor blades were damaged and 2 tail rotor blades were destroyed. **NTSB Final: Pilot error.** Failure to maintain clearance from power lines. Sun glare was a factor.
4/3/99 @ 2350	BO-105 N105HH	Flight for Life	Las Vegas, NV	INT	PRF	CRU	0	3F	Night	IMC Snowing	PIF	Destroyed	Metro Aviation	Helicopter crashed as they were returning to a remote base after delivering a patient to Valley Hospital Medical Center. **NTSB Final: Pilot error.** Continued VFR flight in deteriorating IFR conditions resulting in spatial disorientation and subsequent loss of control.
4/11/99 @ 1645	BK-117 N163BK	Bay Flight	St. Petersburg, FL	ONS	PGT	HOV	0	3N	Day	Clear	No	Significant	RMH	While lifting off and hovering, tail rotor struck hangar. Tail rotor and skids damaged. Damage to building. **NTSB Final: Pilot error.** Failure to maintain visual separation with building.
5/15/99 @ 2122	222UT N781SA	Lifeline	Rockford, IL	ONS	PGT	APP	0	3N	Night	4000 ft ceiling, 4mi vis.	No	Substantial	Air Methods	On approach to scene in rural area, hard landing occurred into field. Damage to skids, tail boom and nose cowling. **NTSB Final: Pilot error.** Misjudged flare during landing.
6/14/99 @ 2208	S-76A N2743E	University of Kentucky	Lexington KT	OTH	N/A	CRU	0	4F	Night	IMC Fog; < 1/4 mile visibility; Winds calm	No	Destroyed	PHI	IFR flight, 2 pilot aircraft. Relocation flight from remote airport (1,381 ft MSL) base back to hospital. After take-off, at about 1,600 feet, the co-pilot (SIC) who was flying, began a descending left turn and subsequently crashed into rising terrain on a tree-covered slope at ~ 1,000 ft elevation. **NTSB Final: Pilot error.** Failure of the PIC to adequately supervise the SIC, and maintain a positive climb.
7/17/99 @ 1231	BK-117 N110HH	Hermann LifeFlight	Houston, TX	INT	PGT	CRU	0	3F	Day	Rain in the area	No	Destroyed	Own Part 135	Helicopter was on approach to an intermediate refueling site during an interhospital transfer. A witness saw pieces of the main rotor system separate from the helicopter before the crash. **NTSB Final: Mechanical failure.** Corrosion of the tension-torsion strap resulting in fatigue cracking and subsequent separation of the strap and main rotor blade from the helicopter.
8/10/99 @ 1138	206L N810F	LifeBeat Air Medical	Cape Giardeau, MO	INT	PGT	TKF	0	3N	Day	N/A	No	Substantial	St. Louis Helicopter	A back-up helicopter was in service. Upon takeoff, reaching the edge of a rooftop hospital helipad, the aircraft did an abrupt and violet yaw to the left, the nose tucked downward and the aircraft started loosing clearance. Pilot landed the aircraft on the paved street below, but the tailboom hit a brick wall. **NTSB Final: Pilot error.** Inadequate preflight planning / preparation — auxiliary power unit cord was attached to the helicopter during the helicopter's takeoff attempt.

Date Time	Aircraft N Number	Program	City, State	Mission Type	Mission Phase	Phase of flight	Pt	Injuries	Day/Night	Weather	Fire	Aircraft Status	Operator	Comments/Description/NTSB Probable Cause(s)
9/10/99 @ 0314	BO-105 N911HR	First Flight	Melbourne, FL	ONS	PGT	APP	0	3S	Night	Foggy	No	Significant	Metro Aviation	Approaching a scene LZ, the helicopter began to descend rapidly from ~ 300 ft. Pilot applied collective control and engine power, but the helicopter continued to descend, colliding with trees and then rolled onto its right side in swampy terrain. **NTSB Final: Pilot error.** Failure to recognize entry into settling with power during approach to land and failure to take remedial action to escape from settling with power.
11/17/99 @ 1350	206L–1 N519EH	Mercy Flight/ Medflight	Great Falls, MT	ONS	POB	TKF	1	4N	Day	Wind gusts to 15 knots	No	Substantial	Omni-flight	Helicopter responded to a ski resort, with the LZ in an open area near ski lift towers. On take-off, with trees directly in front, the pilot decided to turn the helicopter to the left, hover to an open area and depart downslope. . . ." After the helicopter moved left 20-30 ft, the pilot felt the tail of the helicopter "rotate abruptly left." Pilot tried to maintain control and return to the LZ, but the tail rotor struck a lift tower. Helicopter landed hard. **NTSB Final: Pilot error.** Clearance from an object was not maintained. Gusting wind conditions was a factor.
02/26/00 @ 0200	412 N411UT	LifeStar	Knoxville, TN	ONS	PGT	MAN	0	3N	Night	Clear Night	No	Significant	Own Part 135	Aircraft had arrived on scene and was repositioning in the LZ due to presence of a steep slope. The tail rotor struck a small tree while maneuvering. After contact, the TR and TR gearbox separated from the aircraft. Flying debris from separating components caused further damage to aircraft fuselage. **NTSB Final: Pilot error.** Failure to maintain visual lookout resulting in collision with tree.
3/10/00 @ 0605	BO-105 N335T	Lifestar	Amarillo, TX	ONS	POB	CRU	1	4F	Night	Fog	PIF	Destroyed	Temsco	Responded to a scene reportedly close to the TX/OK state line. Fog reported forming while the aircraft was on scene. The pilot and crew lifted with a patient on board at ~0605. No radio communication was established after lift-off. Due to fog in the area, wreckage was not found until ~1100 hrs. **NTSB Final: Pilot error.** Failure to maintain control of aircraft as a result of continued flight into known adverse weather. Factors include dark night conditions, fog, low ceiling, and pilot's lack of total instrument flight time.
4/14/00 @ 1610	222 N225LL	Lifelink III	St. Paul, MN	OTH	PRF	CRU	0	2N	Day	Clear	No	Significant	Air Method	During cruise, pilot lost of control of aircraft and landed on a two story building. Major damage to skids. No injuries. **NTSB Final: Mechanical.** Pylon mounted support assembly separated from transmission case due to fatigue failure of the threaded studs and dowel pins, resulting in failure of the flight control system; also, inadequate maintenance procedures by company maintenance personnel.
4/25/00 @ 1215	BK117 N428MB	Bayflight	St. Petersburg, FL	INT	PRF	CRU	0	3F	Day	Not a Factor	No	Destroyed	RMH	Crew had dropped off a patient at Bayfront Medical Center. Departed for base (8 min flight), flying a new route in response to noise complaints from neighbors along the previously direct route. 3-4 min into flight, collided with the radio transmission tower guy wire and the steel tower 480 feet above the ground. **NTSB Final: Pilot error.** Failure to maintain clearance with tower resulting in collision.
5/6/00 @ 2335	BK 117 N911NC	University Hospital	Cincinnati, OH	FUL	N/A	LNG	0	1N	Night	VMC	No	Substantial	PHI	After crossing the edge of the LZ and almost in a hover, he heard a loud noise or bang from the rear of the helicopter. Simultaneously, the left rudder pedal pushed rearward, and the nose started to move to the right. Pilot made a hard landing. **NTSB Final: Pilot error.** Misjudgment of closure rate resulting in collision with building. Factors involved: tailwind and stuck windsock.

Date Time	craft N Number	Program	City, State	Mission		Phase of flight	Pt	Injuries	Day Night	Weather	Fire	Aircraft Status	Operator	Comments / Description / NTSB Probable Cause(s)
				Type	Phase									
7/16/00 @ 0140	BK 117 N312LS	Life Star (Texas)	Allen, TX	ONS	PGT	LNG	0	3N	Night	Not a Factor	No	Destroyed	Omni-flight	While maneuvering aircraft at an LZ of a scene response, the tail rotor struck a tree. **NTSB Final: Pilot error.** Failure to maintain obstacle clearance while hovering.
7/24/00 @ 0230	A Star N911AM	Georgia Baptist Life Flight	Atlanta, GA	INT	PRF	CRU	0	3F	Night	Clear	No	Destroyed	Critical Care Med-flight	Aircraft was returning from a call in Sylvester, GA. Radio contact was lost at 0230. There was no Mayday or distress signal. The aircraft was found in a wooded area. **NTSB Final: Pilot error.** Pilot experienced spatial disorientation resulting in loss of control of aircraft. Factors involved: dark night light conditions.
7/28/00 @ 1140	222 UT N224LL	Life Link III	Minneapolis, MN	UNK	N/A	TKF	0	1N	Day	Clear	No	Substantial	Air Methods	On liftoff from the helipad, the tail rotor hit the pad light. The pilot landed and shut down the helicopter. **NTSB Final: Pilot error.** Inadequate preflight, improper vertical takeoff, and not obtaining clearance from helipad light. Factors involved: tailwind takeoff, helipad light.
10/16/00 @ 2355	AS355 N355DU	Duke Life Flight	Durham, NC	INT		CRU	0	1F	Night	Clear	UNK	Destroyed	CJI	Enroute to hospital, the main rotor gearbox (MGB) oil pressure warning light illuminated. After landing the crew went by ground. Mechanic believed the oil pressure switch had failed and disconnected the wire. The pilot did a run-up and hover. The AC then took off and was reported down 16 minutes later. **NTSB Final: Mechanical.** Failure to comply with manufacturer's instructions for correcting illuminated main rotor gearbox oil pressure warning light, resulting in failure of the main rotor gearbox due to oil starvation, loss of main rotor RPM, and an uncontrolled descent.
10/14/00 @ 1227	206 L N2233F	Classic Lifeguard III	Jacob Lake, AZ	ONS	POB	TKF	1	4M	Day	Not a factor	No	Destroyed	Own Part 135	On takeoff from scene, hit trees. Possible loss of tail rotor effectiveness. **NTSB Final: Pilot error.** In-flight loss of control during lift-off due to improper planning and decisions. Factors involved: high-density altitude, helicopter weight, and lack of suitable take-off area.
11/13/00 @ 2048	BO 105 911VH	Flight for Life	Pahrump, NV	ONS	PGT	LNG	0	3N	Night	Not a factor	No	Substantial	Metro Aviation	Responding to scene. 2 feet off the ground ready to land when a vehicle entered its LZ. The pilot was about to ascend when he noticed a set of power lines in his path. He powered up to turn around when his skid hit the ground and the helicopter landed on its side. Pilot was able to climb out, crew had to be "cut out". **NTSB Fact finding document.**
12/18/00 @ 1530	365 N1 N89SM	None	West Mifflin, PA	MAT			0	3M	Day	Not a factor	No	Destroyed	CJI	Tail rotor control loss during post-500 hr maintenance operation check. Several attempts were made to land. On the last attempt the pilot lost control and executed a controlled crash landing. NOT COUNTED IN TOTALS.
12/22/00 @ 0331	206 N288JB	Critical Air Medicine	Wilcox, AZ	INT	PRF	LNG	0	3M	Night	Not a factor	No	Substantial	Critical Air Med	Pilot experienced sudden onset of illness due to apparent food poisoning. A very hard landing was made at Wilcox Airport. **NTSB Final: Pilot incapacitation.** Due to nausea. Pilot collapsed onto cyclic causing inadvertent main rotor contact with ground.
01/22/01 @ 0005	206 L-1 N61AE	Air Evac	Quincy, IL	INT	PGT	TKF	0	1F on ground 2N	Night	Clear	No	Minor	Air Evac EMS Inc.	Hospital security officer walked underneath the tail boom while the AC was running. The officer was struck in the head by the tail rotor resulting in a fatal wound. **NTSB Final: Ground crew error.** Security guard failed to maintain clearance from tail rotor.

Date Time	Aircraft N Number	Program	City, State	Mission Type	Mission Phase	Phase of flight	Pt	Injuries	Day/ Night	Weather	Fire	Aircraft Status	Operator	Comments / Description / NTSB Probable Cause(s)
02/28/01 @ 1024	412 N412SM	St.Mary's Air Life	Grand Junction, CO	MAT			0	1F	Day	Not a factor	No	Destroyed	PHI	Departed the hospital helipad for post maintenance test flight that required autorotation. Impacted the ground approximately 24 minutes later, 11 miles south of Grand Junction. **NTSB Final: Pilot Error.** Pilot failed to maintain rotor speed during an intentional autorotation, resulted in a loss of control.
03/23/01 @ 1520	206L1 N2138Y	EMS Air Services of NY	Seneca Falls, NY	UNK	UNK	CRU	0	2S	Day	Not a factor	No	Substantial	EMS Air Services of NY	Pilot heard bangs and experienced yawing and power loss. He determined that tail rotor thrust was lost. Upon precautionary landing the aircraft rolled. **NTSB Final: Mechanical.** The loss of a bolt in a Thomas coupling on the tail rotor drive shaft, for undetermined reasons, during climb, while operating over unsuitable terrain.
04/06/01 @ 1715	222UT N222LF	Wyoming Life Flight	Alcova, WY	ONS	PGT	LNG	0	3N	Day	Not a factor	No	Substantial	CJ Systems	In hover, pilot attempted to reorient aircraft when the tail rotor struck a 55-gallon barrel. Aircraft landed with damage. **NTSB Final: Pilot Error.**
04/23/01 @ 1430	206L3 N215M	Critical Air Medicine	Phoenix, AZ	INT		CRU		3N	Day	Clear	No	Substantial	Critical Air Medicine	Aircraft experienced total power loss and pilot completed an autorotation landing. **NTSB preliminary.**
05/05/01 @ 1700	BO-105C N105RH	Mercy Flight	Medford, OR	INT	POB	CRU	1	4N	Day	Not a factor	INF	Substantial	Own 135	Power loss and fire in #1 engine. Emergency landing at airport and fire extinguished by airport personnel. **NTSB preliminary.**
06/03/01 @ 1620	369D N1109V		Hanapepe, HI	ONS	PGT	CRU	0	4N	Day	Not a factor	No	Substantial	Smokey Mountain Helicopters	Not dedicated EMS. Enroute with firefighters to pick up a "medical emergency" and experienced engine failure. Autorotated into trees. **NTSB preliminary.** NOT INCLUDED IN TOTALS.
07/20/01 @ 1603	BK117 N313LS	North Texas LifeStar	Addison, TX	INT	PGT	CRU	0	2S 1M	Night	Clear	NO	Substantial	Omni-flight	While enroute an engine failed. While turning towards the airport the 2nd. Engine failed. The AC crashed. **NTSB Final: Pilot Error.** Failure to follow preflight checklist and turn on fuel pumps resulting in fuel starvation and power loss.
07/21/01 @ 0049	S-76 N769BB		Los Angeles, CA					1M	Night	Not a factor	No	Substantial	Helinet Aviation	Had transported an organ harvest team to hospital. Helicopter rolled onto its right side while standing unmanned with both engines operating and rotors turning. **NTSB Fact.** NOT INCLUDED IN TOTALS.
08/18/01 @ 1425	355F1 N53LH	Care Flight	Reno, NV	ONS	POB	TKF	1	4N	Day	Clear	No	Substantial	RMH	Pilot lost visual reference upon takeoff from accident scene (brown out). Attempted to land and aircraft rolled over. **NTSB Final: Pilot Error.** Selection of unsuitable landing zone.
09/22/01 @ 2006	AS350 N911NT	Enloe Medical Center	Chico, CA	ONS	PGT	LNG	0	1F 1S 1N	Night	Clear	No	Destroyed	Enloe Medical Center	Approaching LZ at scene encountered a brown out and aborted landing. Attempted landing a second time with flight nurse using night vision goggles and encountered brown out and aborted landing. Impacted trees and crashed. **NTSB preliminary.**
10/07/01 @ 2250	AS355F1 N911BB	Southwest Helicopters, Inc.	Rosebud, TX	ONS	PGT	CRU	0	2M 1N	Night	Clear	No	Destroyed	Southwest Helicopters, Inc.	Difficulty finding scene and crew informed pt. to be taken by ground transport. Both engines lost power and pilot initiated autorotation resulting in a hard landing and slide. Aircraft separated from skids and came to rest on its side. Fuel system found to have a total of 2 quarts of fuel. **NTSB preliminary.**
10/19/01 @ 1458	350B2 N111DT	Med Air	Roswell, NM	PR	N/A	DEC	0	2F 2S	Day	Not a factor	UNK	Destroyed	Medical Air Transport	LZ training. 2 police officers killed, pilot and another police officer serious. **NTSB preliminary.**

Date Time	ircraft N Number	Program	City, State	Mission Type	Mission Phase	Phase of flight	Pt	Injuries	Day/ Night	Weather	Fire	Aircraft Status	Operator	Comments / Description / NTSB Probable Cause(s)
11/09/01 @ 1445	A119 N119RX	IHC Life Flight	Ogden, UT	INT	N/A	APP	0	2M	Day	Clear	No	Significant	Own Part 135	Upon approach, rotor RPM decayed and did not recover. Hard landing and skids torn off and aircraft rolled onto side. Flight was for a survey of new helipad. **NTSB Final: Mechanical.** Improper rigging of the rotary variable differential transformer by the manufacturer, resulting in incorrect fuel scheduling to the fuel control unit.
11/14/01 @ 0033	BO-105 N93LF	Bannock Life Flight	Pocatello. ID	MAT	N/A	CRU	0	1S	Night	Not a factor	PIF	Destroyed	Own Part 135	Pilot landed as a precaution secondary to fuel transfer pump problem, Medical crew and patient went by ground. Mechanic arrived 5 hours later to repair aircraft. Pilot took off and was returning to base and experienced decreased visibility and crashed. The mechanic saw "a bright glow" and followed the flight path of the aircraft. The mechanic extinguished the fire, disconnected the battery, and called for help. **NTSB Final: Pilot error.** Failure to maintain adequate clearance of terrain during initial climb.
01/18/02 @ 0025	BK 117 N626ME	University Hospitals MedEvac	Cleveland, OH	OTH	PGT	TKF	0	2F 1S	Night	Not a factor	UNK	Destroyed	CJ Systems	AC lifting from rooftop helipad when it struck side of hospital and crashed to ground. **NTSB preliminary.**
01/20/02 @ 0750	109 N55NW	Airlift Northwest	Seattle, WA	ONS	PGT	TKO	0	1S	Day	Light Rain 3000 ft. ceiling	No	Significant	CJ Systems	Power loss shortly after takeoff necessitating emergency landing from altitude of approx. 300 ft. Initial return flight aborted due to weather. Attempted to return to base the following day when crash occurred. **NTSB preliminary.**
03/21/02 @ 1335	AS-350B N1184H	Mountain Life Flight	Susanville, CA	OTH	PRF	CRU	0	1F 2S	Day	Not a factor	No	Substantial	Mountain Life Flight	AC returning to base and collided with the surface of lake. **NTSB preliminary.**
6/21/02 @ 1207	AS-350-B2 N852HW	LifeNet	Norfolk, NE	INT	PGT	CLB	0	3F	Day	VFR	No	Destroyed	RMH	Pilot informed dispatcher of a "pedal binding in the right pedal." At 50 to 100 feet AGL aircraft "started spinning and descending until the nose dropped and the helicopter impacted the terrain." **NTSB preliminary.**
09/07/02 @ 0428	222UT N417MA	Mercy Air Services	Nipton, CA	ONS	PGT	CRU	0	3F	N	VFR	PIF	Destroyed	Mercy Air	En route to accident scene. Witnesses reported aircraft was "flying low and very fast" and impacted the ground nose-low. Post-impact fire occurred. No distress call or problems reported. **NTSB preliminary.**
09/09/02 @ 2152	206 N400SL	Careflight	Sioux Falls, SD	INT	POB	UNK	1	4F	N	UNK	UNK	Destroyed	Omni-flight	Aircraft was enroute to Sioux Falls, SD. Last position report was at 2158. Aircraft was found by farmers in a soybean field at approximately 0930 (9/10/02), not far from last position report. There was no distress call. **NTSB preliminary.**

Key:

Mission Type		Mission Phase	Phase of Flight			Injuries	Fire
FUL Refueling	PR Public Relations	PGT Going to get the patient	APP Approach	DEC Descent	MAN Maneuvering	N None	INF In Flight
INT Interhospital	TNG Training	POB Patient on Board	CLB Climb	HOV Hover	TKF Takeoff	M Minor	No No Fire
MAT Maintenance	OTH Other	PRF Returning from patient	CRU Cruise	LNG Landing	TXG Taxing	S Serious	PIF Post-Impact Fire
ONS Onscene						F Fatal	UNK Unknown

Sources: LeRoy Jackson, Air Methods; Connie Schneider, Fitch and Associates; CONCERN Network; *NTSB Aviation Accident Synopses, <http://www.ntsb.gov>; and Preliminary Helicopter Accident Reports, <http;//safecopter.arc.nasa.gov>.*

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EDITORIAL COMMENTS

SK MANAGEMENT, BENEFITS AND COST

Dr. Blumen kindly asked me if I would comment on this penetrating and in-depth report. As someone who has never been shy about offering an opinion about EMS safety, I welcomed this opportunity to contribute as one who has loved this avocation for many years. First, I would like to commend Ira and the UCAN Safety Committee for this thorough and comprehensive labor of love. Much time and energy has gone into this effort and I hope it may change the way we look at EMS aviation safety evermore.

"Consensus is that the current EMS helicopter safety record is appalling. Unfortunately, that is the only consensus among the various participants. There is not even agreement about what constitutes an EMS accident. In 1986, for example, one can cite from reputable sources that there were 16 EMS accidents (*Hospital Aviation Magazine*), or 22 (*American Medical News*), or 28 as reported by CBS television's *Sixty Minutes* or *icopter News*, or 14 or 17, as reported y the FAA in two separate forums. Similarly, the number of EMS helicopter fatalities has been variously reported as 13, 15, 19, 21, and 25."[1] This is from an article by Ira Rimson, written in the National EMS Pilots Association's *Air Net* in 1987. Reporting methodology continues as a problem for statistical purists even today. We do, however, continue to see the same type of accidents with the same persistent causes as years past. Whether or not statistics indicate a trend or a community-wide problem does not override the fact that one (preventable) accident is too many.

Although this report attempts to collate all available information concerning EMS Aviation Safety or occasional lack thereof, quantifying EMS aviation operations and accidents has been imprecise, to say the least. Although the numbers and underlying causes have been a challenge to decipher due to inconsistent methods for classifying EMS accidents, idents, forced, precautionary, and hard dings, we still can draw valid and helpful information as to the risks involved. The statistics at a macro level are important—but management of the risks happens at a local program and personal level. It is important not to get too wrapped around global statistics and get more concerned about managing safety at the level we can truly affect. As A. E. Housman states, "Statistics in the hands of an engineer are like a lamppost to a drunk—they're used more for support than illumination." I would recommend that you take all of these studies and boil them down to something usable at your base. A local risk assessment, based on the hard, cold lessons of others, may help you look more honestly at yourself. If you derive nothing worthwhile from this entire study or believe that it only happens to someone else, you may wish to look into the mirror for the problem.

Probably the first civilian EMS accident in this country occurred in May 1978 in an Alouette and its cause was reported as mechanical and engine-related. That was not, however, where an early underlying cause for EMS accidents was born. If we only look into accidents from the civilian sector of EMS we will miss some valuable clues to some very basic risks and causes of EMS accidents. Critical patients were being flown long before the first hospital-based program began in Colorado in 1972. As early as 1970, military air ambulance organizations returning from Viet Nam were beginning the Military Assistance to Safety and Traffic program (MAST). Helicopters had been extensively used to transport the wounded, sick, and injured in the Korean and Viet Nam wars and as far back as Burma.

The MAST program utilized military aeromedical assets and personnel to provide much needed assistance to the civilian sector. Military air ambulances began to provide emergency transportation of sick and injured from the streets and highways in several states. By the late seventies, more than two dozen locations throughout the nation were served by military emergency aviation services. The entire EMS arena in the United States was beginning its transition into the sophisticated and responsive systems we see today. The MAST program was a critical link in the system's genesis as well as a model for EMS aviation in the civilian sector. The MAST program also suffered from some of the similar stressors that have carried over to today's EMS aviation cultures. Pilots who risked their lives evacuating their fellow soldiers from the mountains and rice paddies of Viet Nam were now being asked to do the same for their fellow citizens on the farms, highways, and mountains of the United States. This ingrained noble and very human drive, which perhaps could be termed "the rescuer ethic," still compels much of what we do and feel today.

Having served in this avocation as both a military and civilian EMS pilot, it is a pressure that one feels every time the tones go off. It is why many of us do this work. It is the adrenalin jolt that drives us to do great things. It drives us into taking risks. It occasionally pushes us to take foolish risks and go beyond our best judgment. Sometimes that risk-taking pushes us beyond recovery. There is a time for heroes, but whether or not that is a risk we can really accept needs to be addressed directly with each member of an air medical team, management, and the communities we serve.

This underlying ethic is one common to the dispatchers, pilots, nurses, paramedics, physicians, program managers, policemen, firemen, and almost everyone involved in the emergency and public safety field. To deny that the "rescuer or hero mentality" exists is to somehow deny who we are or who we want to be. It is also something that rarely appears on an EMS aircraft accident report. It is difficult to quantify and a bigger challenge to manage. It is the "elephant in the road" that no one readily admits to. It is a very real characteristic that drives us to do what we do—yet is seldom addressed as a core value or accident cause.

Every time I read an accident report where the pilot and crew perish in a blinding snowstorm, foggy meadow, driving thunderstorm, or pitch-black hillside I always ask, "What were they doing there?" "Why didn't they turn back?"

"Why did they go at all?" Often as not, the team is on their way home or transferring a relatively stable patient who might as easily been transferred by ground ambulance or waited a few hours in their hospital room. Combine the *hero mentality* with *get-homeitis* and we have a deadly mix. Look at the statistics throughout this report and you will see some of the catastrophic results of pilots and crews unnecessarily flying into deteriorating weather conditions or pushing well beyond their personal limits. Most helicopter operators train their pilots to have a corporate, professional mentality. That is a good start. We cannot deny that there are many pressures on an EMS pilot that bring the "rescuer mentality" to the surface. How we as an EMS community deal with this intense drive to help others is a topic that the EMS aviation community must openly and regularly discuss. A written policy is just eyewash and falls far short of effective risk management.

If we look at NTSB accident reports and accept them at face value, we will be limited in truly understanding the core values that really created the accidents. In those reports we will find that "the pilot flew into a hill, hit wires or buildings, or disregarded regulations or company policies and procedures." Those are real causal elements—but simply do not go deep enough. We must understand the organizational culture and personal values that drove a pilot into a situation that was needless and preventable.

Human factors remain as the number one cause of EMS accidents. "A study of 87 accidents form 1987 through 2000 found that human error was the primary causal factor in 76 percent. The greatest concentration of human error occurred in the en-route phase of flight and often involved faulty in-flight planning and decision making or inadequate evaluation of weather information."[2]

In his 2001 study, Pat Veillette found that "forty-one of the 87 accidents (47%), including 26 of the 32 fatal accidents (81%) occurred during the en-route phase of flight. Of the en-route accidents, 68% resulted from human error."[3] "Twenty-six percent of the accidents—and 53 percent of the fatal accidents—occurred in low-visibility or instrument meteorological conditions."[4]

In the EMS Line Pilot survey conducted by NEMSPA and HAI in 2000-2001, pilots who flew Emergency Medical Service helicopters reported that management or crew pressure was most often the greatest risk to safety as a whole in the industry. It was closely followed by night operations, inexperience, weather reporting or forecasting, and poor decision making. When asked about factors that have contributed to the rise in EMS accidents, pilots responded with "pushing weather minimums, complacency, lack of IFR training, and inexperience."[5]

EMS pilots are routinely called upon to launch on a moment's notice, day or night, 24/7, to unprepared landing zones with marginal weather reporting for their destination(s) and routes. This substantially raises the risk over that of the average commercial pilot who is able to fly from approved airport to approved airport with adequate planning time and official weather reporting. Throw in a palatable sense of urgency and the stage is set.

The *Air Medical Accident Analysis* report, conducted by the subcommittee resulting from the April 2000 Air Medical Summit, performed a thorough study of 20 air medical accidents that occurred from 1993 through 2000. As background, this report stated: "Between 1987 and 1997, there were on average four air medical helicopter accidents per year for the industry. By 1997, the accident rate for AMS (Air Medical Service) operations had been reduced to 1.97 accidents per 100,000 flight hours from a high of 17.08 in 1987. In 1998, however, the number of accidents rose to a nine year high of seven, but more alarming, was the rise of fatalities to fourteen, the highest number since the peak year of 1986. In 1999, the number of accidents rose even higher to ten, the highest also since the peak year of 1986. Fatalities were down to ten but still higher than the average of six."[6]

We have discussed statistics and safety risks throughout Dr. Blumen's document. I would like to move our focus to the solutions. Some of these are technological and institutional. I would submit, however, that the real answers are in strong personal and organizational safety cultures enforced by proactive and aware management. Levelheaded professionals must replace risk takers and adrenalin junkies. Pilots and crewmembers who place safety values below that of personal thrill seeking or a mistaken sense of heroics must change their spots or find new professions. Managers, hospital administrators, accountants, and program directors must insure that their pilots and flight teams have proper tools and facilities to do their jobs safely.

Technology will provide stronger, more dependable, and ergonomically friendly equipment, both in the aircraft that we fly and in the gadgets associated with flight following, air traffic control, terrain avoidance, GPS, night vision equipment, avionics, flight instrumentation, and controls. Many are readily available today. Many flight programs today are using 30-year-old technology, underpowered, or marginally safe aircraft, and expecting their pilot and flight teams to make due. Some programs continue to ask their pilots to fly multiple and dissimilar airframes on a routine basis. Some programs utilize a spare aircraft that is dissimilar or inadequate for the mission. There is a managerial blind eye to the risks that those cost-saving measures create. Often budget constraints and a politically driven decision process exclude the pilot effectively from the aircraft selection process. Occasionally, the RFP process creates a situation where costs take priority over safety. Medical personnel often have the final word in selecting the aircraft and often do so based on medical needs with token regard to the most important tool in the process—the aircraft. There are many aircraft in use today that are missing what I would consider critical elements for an optimum EMS helicopter.

These critical aircraft requirements, in my opinion, are *one* single type aircraft with an adequate margin of power and performance to do any of the missions a program requires in its area of operations. This should account for weather, terrain, and all environmental factors. The aircraft should have adequate avionics, lighting, and safety features. It should have sufficient space, efficient medical configuration, and ergonomics to safely and efficiently treat the type and number of patients to be flown. A single type of helicopter model with similar ergonomics and systems in the program aircraft reduces risks and maintenance complications as well. Dissimilar aircraft create another obvious risk ignored by many programs and operators. Perhaps there is und risk management reason why a uthwest, United, or Delta pilot remains solely on one airframe, type, and model. Aside from the obvious training, standardization, and maintenance advantages, there are very valid and often ignored risk management reasons to keep pilots in only one aircraft type and model. If you've ever rented a car different than the one you drive at home and searched for the parking brake release or windshield wiper button in a dark parking lot or rainy freeway, you should understand the term "negative habit transfer." One question is whether or not thinly stretched community, hospital, or program director's budgets are willing and able to afford that in the future—or even in the present.

The other question is whether or not operators or programs are really willing to take ***all*** of the steps necessary to aggressively manage risks. Hospital and corporate CFOs who approve budgets must not be lured into false economies that elevate ks. Insurance companies and governnt agencies are now, or will be, exerting their influence on unsafe, ineffective or redundant programs. The MBA mentalities who believe profits and costs are the only measures of good business must add safety as an equal partner to their thought process. If we want to make a difference in our day-to-day risk management, we must take a hard look at how *"that's the way we've always done it"* affects us today.

The Air Medical Service Safety Summit's *Air Medical Accident Analysis Final Report*[7] concluded its study of 20 recent air medical accidents with the following interventions that rated high in both effectiveness and feasibility. They were:

- Enhance the training for night flying operations
- Enhance the training for mountain flying operations
- Equip aircraft with Terrain Avoidance Warning Systems (TAWS)
- Equip aircraft with Radar Altimeters
- Provide aircraft with mission-essential equipment
- Improve the content of weather briefings

The top six in the high effectiveness and moderate feasibility were:

- Conduct/enhance annual IFR proficiency checks
- Conduct/enhance training to improve understanding of weather briefings
- Enhance overall training in recurrent, professional knowledge, etc.
- Conduct/enhance training in Aeronautical Decision Making (ADM)
- Establish integrated and structured Pilot Training Programs
- Conduct/enhance mission-oriented training

This report was distributed to the Air Medical Services subcommittee of HAI, the Air Medical Safety Advisory Committee (AMSAC), and the AAMS/CORE Safety Committee for their review and suggestions. A major key to the training issue is that it should be mission oriented. If the pilot is expected to find and land in an LZ in the mountains on a pitch-black foggy night or land in a dusty or snowy LZ, regular and recurring training should meet that requirement. Unfortunately, many operators routinely train on safe and sterile runways or helipads. If we are to truly lower our risks, we must train in the same environment and mission conditions we will encounter. Instrument training should involve real inadvertent IMC situations under real mission profiles. In the real EMS world, this means that training dollars must come from vendors and programs alike to better manage risks. We have some real solutions. We must have the will as well.

When the EMS line pilots were asked for their suggestions to improve safety in the NEMSPA line pilot survey, the top vote getter was, "Increase quality and frequency of training." This was following closely by "Improve pilots' salaries and benefits," and "Night Vision Goggles." We need to stop ignoring the hard, cold fact that our pilots cannot see like bats in the dark. We have been pretending somehow for years that once you are an EMS pilot, you become magically endowed with built-in sonar and night vision skills. Pilots and crews must learn to say "no" when asked to perform outside of their limits. The right equipment includes things like night-vision devices, night suns, and skid lighting. If you don't have adequate lighting or NVG assistance, don't use your rotor blades as curb feelers as you plough through a dark night.

Another ominous finding in the NEMSPA/HAI survey was that over 25% of EMS pilots either had not received any crew resource management training or they felt it was ineffective or not well presented[8]. When asked about the effectiveness of their training or preparation for their present position, significant numbers (>10%) of pilots responded that the following areas were weak: Flight crew dynamics or interaction, Crew Resource Management, Aircraft systems, and mission planning.

In response to the need for improving and standardizing Crew Resource Management, the Air Medical Safety Advisory Committee (AMSAC) pushed the development of the Air Medical Resource Management (AMRM) program. Through the efforts of Michelle North, an exportable AMRM package was produced and "Train-the-Trainer" sessions initiated. It is the intention of the AMSAC that it become available to all programs and that they continually train in this invaluable resource.

We should all take heed of one particular result of the EMS pilot survey. *After years of warnings to the EMS aviation community about the need for pilots to make flight go-no go decisions independent of pressure, approximately 20% of pilots surveyed responded that "occasionally, some flight crews do pressure a pilot to launch or continue a mission."* Pilots also responded in significant numbers that they had been pressured to take flights by management and that local competition created some pressure to fly. Pilots were also pressured to speed up launch times creating opportunities to miss critical tasks. Most program managers as well as dispatchers, pilots, and medical crewmembers must control their perceived need to hurry up or pressure pilots. It is clear that some do not. Sometimes our most seasoned medic or nurse is also the most adamant about the "need for speed." Sometimes it is the crewmember who has watched too many

"911" TV shows or has a "Rambo" self-image. These human factors are clearly manageable and these risks avoidable ith effective leadership and personal cipline.

The Air Medical Safety Advisory Committee (http://www.amsac.org/) "was envisioned to be an operator driven forum dedicated to the sharing and development of safety information and initiatives for the AMS industry." It is dedicated to seeking solutions to some of the EMS aviation community's tough issues as they relate to competition, flight and duty time, fatigue countermeasures, standardized criterion for Air Medical Services incident/accident reporting, and other EMS safety issues. The organization continues today with participation from operators, programs, NASA, FAA, insurance, and air medical professional organizations. Ask your operator if they participate. Unfortunately, a few operators have not thought it worth their time and effort.

The bottom line is that there are no new accident causes. If we want to fix what's broken at a human level we need only to look at Pat Veillette's chart at Figure 1-21 of this report and see what pe of human factors are causing accients. The top three are "risk taking, pre-flight planning, and in-flight decision making." We have met the enemy and it is us.

In conclusion, NO pilot should ever have to make critical flight decisions under the thumbscrew of peer pressure, competition, job security, or self-inflicted sense of urgency. If you want a quick barometer of your program's safety culture ask a few key questions such as:

When was the last time someone from the hospital, vendor, or corporate management attended a program safety meeting, rode along at 2:00 AM, or simply sat down in the crew lounge and chatted with the crews about the things that really matter?

When was the last time you did "hands-on" extrication, survival, or crash drills under realistic mission-oriented profiles?

What percentage of your annual and required training is devoted to the biggest and riskiest tool in your medical kit—*the aircraft*—or scene safety—or helipad safety—or weather—or Air Medical Resource Management?

Do your aviation maintenance technicians have adequate time, facilities, resources, and full support to do their critical work?

What happens when everybody knows that one of the pilots is a cowboy or is constantly pushing the envelope?

Who picks your monitors, defibrillators, IV kits, or traction splints? Who picks your aircraft?

What happens if a crewmember, flight communicator, manager, or doctor pressures a pilot or crew to fly?

How often do you train the folks who set up your LZs?

What happens if someone says "no" or "let's go back"?

Can you ask these questions in your organization?

When was the last time you did? Did anything change?

This is hardly a comprehensive list. Each of us should continually and honestly assess our safety attitudes, values, and culture. We don't need any more heroes and monuments to the tragic end of noble intentions. We need enlightened managers who will be fiercely independent and effective when it comes to safety issues. We need as much priority on risk management as we have on public relations, charting, medical training, nursing or paramedic or piloting skills.

How do administrators select their program directors or lead pilots? What skill sets does one need to be a manager? Must a program director be a nurse? Are leadership and management skills more important than medical, nursing, aviation, or technical skills for a manager? How much emphasis is there that leaders thoroughly know and use risk management principles? Do present-day EMS program management courses place a high priority on safety and risk management? How long will we continue to do things the way "we've always done them"?

We need corporations, programs, and operators who *always* put safety first through action not words. We need manufacturers who will produce aircraft that can do the job. There must be adequate, appropriate, and well-maintained equipment that can do the mission. We need pilots who will participate in the process and have the courage to speak out for safety issues and hold their ground. We need safety cultures that support those who say "no" for safety's sake. We need the will and the courage to change. "There are three kinds of people: Those who make things happen, those who watch things happen, and those who ask, "What happened?" –(Casey Stengel)

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CAN WE HAVE BENEFIT WITHOUT RISK?

We are pleased to contribute to defining ntext for the extremely important being presented by Dr. Ira Blumen and his colleagues at the University of Chicago Aeromedical Network (UCAN).

The passion and commitment of practitioners in air medicine is legendary. Following from the successive military experience in Korea and then Vietnam, helicopter evacuation of the critically injured, often in the most dangerous and trying of circumstances, took on near mythic status. The ethos of "finding a way" came home and into the civilian world of air medicine. Thirty years after the first helicopter program began operation at St. Anthony's, the debates about value—the interface of benefit, risk, and cost—continues.

In recent months, Thomas and colleagues in Boston have reviewed and published annotations of the best empirical studies for the use of air medical intervention for critically ill and injured patients.[1, 2] In addition, recent studies comparing cost of intervention[3, 4], increased mortality after program closure[5], and a cost-benefit analy- air medicine[6, 7] increasingly support evidence base for measurable benefits across a wide range of disease and injury processes. Marrying the unique technology of aviation with critical care medicine has not only improved care for the critically ill and injured, but improved access and equity within the healthcare system. But at what cost and is the cost worthwhile? In this case, it is not only the cost of care but also the human cost in lost or impaired lives through aviation accidents.

While the benefits for individual patients and the wider population are demonstrable, it is equally important to understand safety. The issues of aviation misadventure coupled with the Institute of Medicine Report[8], noting alarming rates of medical misadventure leading to preventable death, must give both patients and providers great pause in assessing safety.

Safety throughout medicine is of great concern to individual patients, the public, and providers of care. After a single accident recorded in 1996, the air medical community over the past five years has seen an upsurge in the number of aviation accidents and incidents leading to death and serious injury. How safe is this enterprise and do the benefits outweigh the risks? The earliest test of medicine—"first, do no harm"—must be answered.

The short answer is that it is difficult to answer these questions. We have long assumed that benefits outweigh risks while each of us wonders and worries about experiencing an accident firsthand. While the number of accidents has increased, it is impossible to understand if the actual rate is increasing. To measure rates one must have both a numerator and a denominator—in this case the number of accidents measured against exposure—the number of flights and the number of flight hours. Sadly, and frustratingly, it has been nearly impossible to measure and "how safe" remains virtually unknowable.

Competitive pressures between programs, Part 135 Operators, vendors, the lack of central data repository, and the costs of gathering and analyzing data have all played a part in the creation of a contextual black hole as regards the safety of air medicine. Operators, the FAA, NASA, air medical providers, and insurance underwriters have become increasingly frustrated with the current lack of data. While there have been a number of initiatives in the past two years—the creation of the Air Medical Safety Advisory Council (AMSAC) the ASRS program from NASA, the Root Cause Study Group Report, and the accident database from HAI—the overall understanding of risk and safety remains limited. Why is this important? Simply that the absence of good data and analysis is corrosive on many fronts from poor regulation—rules that do not fix problems, to escalating insurance premiums, media alarm, and most worryingly, to increasing distrust on the part of the public.

The publication of this paper changes the discussion on all fronts. Until this report there has been no real effort to collect or examine the underlying data to truly have any understanding of overall safety and the risks of air medical intervention. Understanding risk is essential for both providers and patients. There are risks throughout medicine and in all ambulance transport, whether by ground or air. The questions each of us must answer in the delivery of any medical intervention and therapy are:

Do we understand the risk and have we taken every step to minimize the risk?, and

Do the benefits outweigh the risks?

This paper by Blumen, et al., is a huge step forward in answering these questions. While the gathered research is still limited by the lack of a central repository, the gathered and compared data from many fronts allows a reasonable set of assumptions to measure risk and safety in air medicine. Stated another way, the real question is: Can we eliminate the medical risk in any given therapy and at what cost to benefit? The answer is no—without at least some risk we would not have benefits.

Most importantly the final sections of the report look at the risk to providers and patients. The news is sobering to providers while good for patients. Without question the issue of risk is tied to exposure. This is a message we must take home. Managing risk—identification, avoidance, reduction, and management are key strategies that each of us must employ ever day. Every provider and participant in air medicine should read and re-read this report, take it to heart, and then change your practice.

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ANGELS OF MERCY OR ANGELS OF DEATH

In the late 1980s a television newsmagazine referred to the air medical industry as the "Angels of Mercy or Angels of Death" in reaction to the high accident and fatality rate. This rate reached an all-time high of 13.14 accidents per 100,000 hours flown. In contrast, during this same time frame commercial airliners were experiencing a rate of .002/100,000 hours. As this safety report has shown, the accident rates and fatal accident rates per 100,000 flight hours are down dramatically from what we experienced in the mid-'80s. Unfortunately, from 1998 through 2001, we have had more accidents than in any four-year period in HEMS history, including the "death star" years. In addition, the fatal accident rates are the highest they have been since the early 1990s.

What has changed and what has not? We are flying more sophisticated equipment. Oddly enough, during a recent Helicopter Association International Exposition Safety Symposium, a group of helicopter manufacturers conducted a panel discussion on the high accident rate. It was their premise that they [manufacturers] have re-designed, re-engineered, re-structured, automated, and improved the basic flying machines, yet we are crashing at the same, if not higher rate than was experienced prior to all these improvements.

We added more pilots to air medical programs to reduce exposure and fatigue while on duty as fatigue was considered to be a major factor in the accident chain of events. We increased weather minimums in the hopes that standards would encourage better decision making. We formed an accreditation group to promote competition in achieving excellence and professionalism. Associations were formed to provide a forum and infrastructure to attack safety issues head on. The industry was aggressive and came together with safety as their coat of arms.

The fruits of this labor seemed to provide quite a harvest as 1990 came to a close with no fatalities. Had we nipped the beast in the bud? Unfortunately, we returned to a smattering of accidents in the early and mid-1990s. The number of accidents began to escalate in 1998 and continued through 2001 when we had 13 accidents.

The industry took a deep breath and said, "where do we go from here?" We re-grouped, met in mass, identified seven initiatives to break the chain of accidents and attempted to provide an action plan with which to proceed. The FAA was anxious for our industry to come up with an in-house solution. But did we?

Unfortunately, unilaterally there has been little change in the way we do business. An Air Medical Resource Management course has been developed. Fielding and implementation is slow as financial support for safety education and training is not uniformly endorsed throughout the industry. The Air Medical Safety Advisory Council was formed in the hopes that Part 135 vendors could provide some insight and solutions to industry safety trends and share information to aid in the prevention of repetitive safety infractions.

As in all organizational structures, progress is impeded by the very large geographical nature of our business. There is an underlying sense of "breath holding" until the end of the day in hopes that another significant event [accident] hasn't occurred. And then a new day begins, as do our hopes. We still hear of repercussions for "whistle blowers" on safety issues. Individuals within organizations are afraid to come forward with safety of flight issues for fear of losing their jobs. Aberrant behaviors are sometimes rewarded rather than punished. Between operators there is little exchange of information for fear of disclosing proprietary issues. Successes as well as failures are not shared. And in these tough financial times in the healthcare industry, competition is the dragon in disguise for faulty decision making, cutting safety corners, eliminating safety infrastructures, training and education, and general apathy toward developing a safety culture.

But all is not lost. There are multiple things your organization can do to get on the safety bandwagon and bring the accident rate to zero. This must, however, start at the top with management buy-in that safety is the only imperative to exceed mission accomplishment.

This report may raise your awareness with regard to safety and some unique risk assessments. But safety must be an integral part of everything your program thinks, says, and does. Safety has to become an attitude and a way of life. You don't "get safe" when you come to work. It must permeate the mind-set of your organization. Resources must be committed to safety training and education. Formal safety standards must be set, must be trained, and must be adhered to. Safe behavior should be rewarded and unsafe behavior should have serious consequences. Open communication must be encouraged. And above all, your organization must develop a safety culture that promotes the motto, "if it's not worth doing safely, it's just not worth doing!"

No, all is not lost, but without aggressive, proactive, and committed attention to individual organizational safety infrastructures, the accident rate will not change, and we may be re-crowned Angels of Mercy or Angels of Death.

Michelle North, Ph.D.
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The Wisdom Well

MAINE MEDICAL CENTER
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PROPOSED HELICOPTER PAD NOISE MITIGATION

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MAINE MEDICAL CENTER
PROPOSED HELICOPTER PAD

EXECUTIVE SUMMARY

Maine Medical Center (MMC) proposes to construct a helicopter pad as part of its Phase I site expansion at its existing hospital in Portland, Maine. Other key elements of the Phase I expansion include a multi-story birthing center and nursery, a utility plant, and an additional seven-story parking garage.

The helicopter landing and takeoff pad (helipad) will be constructed on the top level of an existing parking garage structure bordering MMC and Congress Street. The proposed helipad will improve emergency services by providing medically supervised helicopter flights directly to and from Maine Medical Center for critical patient transfers. The function of the proposed helipad is to provide quick access for the increasing numbers of trauma, cardiac, and other patients. Based on current operations in Maine, helicopter flights to MMC average approximately four flights per week with a possible increase to five or six flights per week once the helipad becomes operational. Experience statewide has shown that about one-third of flights occur between 3:00 pm and 7:00 pm; and just 13% of flights occur between midnight and 8:00 am.

Resource Systems Engineering (RSE) completed an evaluation of sound levels likely to occur in the vicinity of the proposed helipad. RSE measured sound levels of helicopter test flights carried out by LifeFlight of Maine and compiled topographic and design information for the proposed Phase I expansion. RSE also monitored community sound levels at residences nearby MMC to evaluate noise impact from the proposed helipad. A separate report *Community and LifeFlight Helicopter Sound Level Study* dated April 15, 2004 provides a comparison of flight test and community sound levels. LifeFlight of Maine is a full partner in operational noise mitigation and follows noise abatement procedures as set forth in the *Fly Neighborly Guide* published by the Helicopter Association International. These procedures are consistent with advisory circular AC 91-66, Noise Abatement for Helicopters, developed by the Federal Aviation Administration (FAA). The Helicopter Association International enhanced the FAA noise reduction guidelines as part of its *Fly Neighborly Guide*.

The primary objectives of the Noise Mitigation Study were to assist Maine Medical Center in selecting a site for the proposed helipad that would limit noise impact and to investigate additional noise control options to ensure that all practical noise mitigation was being incorporated into helipad design and operations. From test flight results and project data, RSE developed a noise prediction model to calculate sound levels likely to occur from future use of the proposed helipad. The helipad site and associated flight paths were carefully selected based on sound level estimates and community monitoring results to limit noise impact. The noise model confirmed that locating the helipad on the existing parking garage would enable existing and proposed buildings to block sound propagation to noise sensitive areas to the west and south.

Sound level estimates were developed for the helipad site with various construction and mitigation options. Many model cases were run to investigate a myriad of possible mitigation options. Refinement and analysis of noise model estimates showed that the best mitigation option is to face the helicopter toward the north whenever possible during operation on or in close-range to the helipad. Due to prevailing winds the helicopter will typically land facing to the north.

FAA design criteria were found to significantly restrict opportunities for additional mitigation using noise barriers. Through development and analysis of mitigation options, RSE found that an effective noise barrier, serving all areas not mitigated by new structures at MMC, would be too large to be practical for construction. Smaller noise barriers were found to provide no significant additional noise reduction to areas not mitigated by new construction or by facing the helicopter northerly while on or in close range to the helipad.

During the Noise Mitigation Study, RSE also found that FAA design criteria were inherently aligned to the optimum location of the helipad on the existing garage for noise reduction from existing and proposed structures. Further, due to area topography and the barrier effect of the existing garage, there was no significant sound level reduction from absorptive versus reflective surfaces of MMC buildings.

The proposed flight paths and helipad on the existing parking garage will be located in areas where existing community sound levels near MMC are the highest. Because of site topography, the noise model showed that locating the helipad on the existing parking garage would limit the number of residential properties affected by helipad sound levels.

MAINE MEDICAL CENTER
PROPOSED HELICOPTER PAD
NOISE MITIGATION

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LIST OF ACRONYMS

ANSI	American National Standards Institute
ASA	Acoustic Society of America
B&K	Bruel & Kjaer
CFR	Code of Federal Regulations
dB	Decibel (Unit of Sound Pressure Level)
dBA	Decibel A-weighted
DEP	Department of Environmental Protection
F	Fahrenheit
FAA	Federal Aviation Administration
ISO	International Organization for Standardization
HP	Horsepower
Hz	Hertz (cycles per second)
L1	Sound Level Exceeded 1% of a Measurement Period
L10	Sound Level Exceeded 10% of a Measurement Period
L50	Sound Level Exceeded 50% of a Measurement Period
L90	Sound Level Exceeded 90% of a Measurement Period
Ldn	Day-Night Sound Level
L_{Aeq}	Equivalent Sound Level Measured on the A-Scale
L_{Aeqday}	Daytime L_{Aeq}
$L_{Aeqnight}$	Nighttime L_{Aeq}
MMC	Maine Medical Center
Mph	Miles per hour
MRSA	Maine Revised Statutes Annotated
RSE	Resource Systems Engineering

MAINE MEDICAL CENTER
PROPOSED HELICOPTER PAD

NOISE MITIGATION

1.0 INTRODUCTION

Maine Medical Center (MMC) proposes to construct a helicopter pad as part of its Phase I expansion at its existing hospital in Portland, Maine. Other key elements of Maine Medical Center's Phase I expansion include multi-story birthing center and nursery, a utility plant, and an additional seven-story parking garage.

Resource Systems Engineering (RSE) completed an evaluation of sound levels likely to occur in the vicinity of the proposed helipad. RSE measured sound levels of helicopter test flights carried out by LifeFlight of Maine and compiled topographic and design information for the proposed Phase I expansion. From test flight results and project data, RSE developed a noise prediction model to calculate sound levels likely to occur from future use of the proposed helipad.

RSE also monitored community sound levels at residences nearby MMC to evaluate noise impact from the proposed helipad. A separate report *Community and LifeFlight Helicopter Sound Level Study* dated April 15, 2004 provides a comparison of flight test and community sound levels. The following report provides noise model predictions of future sound levels reflecting construction of the Phase I projects and evaluation of noise mitigation options for the proposed helipad.

2.0 SITE DESCRIPTION

The primary hospital site is located between Congress Street and Bramhall Street approximately one-half mile east of Interstate 295 and two miles northeast of the Portland International Jetport. The vicinity of Maine Medical Center is mostly developed land including a mixture of uses. In addition to the hospital and related parking and medical facilities, development along Congress Street is predominantly commercial. Between Congress Street and Park Avenue, there are a considerable number of residential buildings. To the west, St. John Street is predominantly commercial with residential and commercial/medical buildings located between St. John Street and MMC. Areas south and east of MMC are primarily residential with the City's Western Promenade Park and occasional commercial uses as well.

The helicopter landing and takeoff pad (helipad) will be constructed on the top level of an existing parking garage structure bordering MMC and Congress Street. The proposed helipad will improve emergency services by providing medically supervised helicopter flights directly to and from Maine Medical Center for critical patient transfers. The function of the proposed helipad is to provide quick access for the increasing numbers of trauma, cardiac, and other patients. This project is part of a larger Phase I expansion that includes:

- A birthing center to be built at the site of the former New England Rehabilitation Hospital bounded by Ellsworth, Crescent, Wescott and Charles streets. The plan calls for closing Charles Street and connecting the new building to the medical center.

- Expansion and renovation for the Emergency Department to be built in the adjoining basement level space of the new Charles Street building.
- A seven-story parking garage next to the existing garage on Congress Street, featuring enclosed pedestrian skywalks to the medical center. Two homes on Crescent Street purchased by Maine Medical Center will have to be razed.
- A new utility plant between MMC and Gilman Street to the west to provide more efficient heating and cooling for new and existing buildings.

This report addresses sound that will be generated from operation of the proposed helipad. Sound from other portions of the Phase I expansion are not addressed, however, the helipad sound level analysis takes into account the barrier, shielding and reflection effects provided by other parts of the proposed expansion.

3.0 HELIPAD OPERATION

LifeFlight of Maine will provide most of the helicopter flights to the proposed MMC helipad. Since its creation in 1998, LifeFlight has provided emergency medical helicopter services in Maine. LifeFlight operates two Agusta 109C helicopters in Maine: one based at Eastern Maine Medical Center in Bangor and one at Central Maine Medical Center in Lewiston. The Agusta 109C is expected to be the primary helicopter using the proposed helipad at MMC.

LifeFlight is a statewide medical helicopter service that is available 24 hours per day, seven days per week. Helicopter transport is restricted to the most acutely ill or injured patients and a physician must prescribe its use. In addition to the aircraft stationed in Bangor and Lewiston, there are backup aircraft available in the event that one or more of the aircraft are not available.

Based on current operations in Maine, helicopter flights to MMC average approximately four flights per week with a possible increase to five or six flights per week once the helipad is operational. No more than 30% of helicopter flights are expected to occur between the hours of 10:00 pm and 7:00 am. Experience statewide has shown that about one-third of flights occur between 3:00 pm and 7:00 pm; and just 13% of flights occur between midnight and 8:00 am.

For the proposed helipad, the period of helicopter operation on or in close-range to the helipad is expected to be approximately nine minutes per flight. This consists of four minutes for approach, landing, and spool down, and approximately five minutes from the beginning of cold startup through liftoff and close-range departure flight.

The test flights at MMC, addressed in RSE's report of April 15, 2004, involved approach, hovering above the proposed helipad site, and departure consisting of approximately one minute of close-range operation per flight test. The test flights did not include landing and takeoff of the aircraft, or the quieter spool down and startup/warm-up cycles of an actual medical flight.

4.0 SITE SELECTION

MMC evaluated several sites for possible location of a medical helipad. RSE prepared a noise model to estimate sound levels from each possible helipad location. For purposes of site selection, the sound level analysis evaluated helicopter sound levels while operating on the helipad. MMC and others evaluated other considerations such as emergency room access, flight path access, and structural limitations. Possible helipad sites evaluated included the Bean Tower, the existing parking garage, the proposed new parking garage, and the proposed new Charles Street Building.

In conjunction with the helipad noise model, RSE monitored existing community sound levels to determine noise sensitive areas in the vicinity of Maine Medical Center. Existing community sound levels were compared to noise model results to determine the relative noise impact of possible helipad sites. The noise model was developed to represent the Phase I expansion including the Charles Street building and new parking garage. Site profiles showed that the top of the existing parking garage is at a lower elevation than both existing and proposed hospital buildings. Consequently, the noise model confirmed that locating the helipad on the existing parking garage would enable existing hospital buildings and the new Charles Street building to block sound propagation to noise sensitive areas to the west and south. Because of site topography, the noise model showed that locating the helipad on the existing parking garage would limit the number of residential properties affected by helipad sound levels.

Further analysis was conducted to determine if sound would reflect off existing and proposed structures and increase noise impact on residential properties. The nearest residential properties to the parking garage are across Congress Street and at much lower elevation than the top level of the parking garage. Consequently, helipad sound that reflects off the hospital buildings would be blocked by the existing parking garage and therefore will not increase noise impact of the helipad at nearby residential properties.

Another criteria for reducing noise impact is to locate the helipad in an area where community sounds are relatively high. The results of community sound level monitoring shown in Table 1 (see also Flight Test Report 4/15/04) show that the highest daytime and nighttime community sound levels occurred at position CP-2 across Congress Street from the existing parking garage. Therefore, the existing parking garage would put the helipad where the highest existing community sound levels occur. The primary source of existing sound levels at CP-2 is traffic on Congress Street. A vicinity site plan showing Maine Medical Center and the community monitoring positions is shown as Figure 1.

TABLE 1

Existing Daytime and Nighttime Sound Levels

	Maine DEP Average Hourly L_{Aeq}		**City of Portland Average Hourly L_{Aeq}**		
Monitoring Position	**Daytime 7 am to 7 pm**	**Nighttime 7 pm to 7 am**	**Daytime 7 am to 9 pm**	**Nighttime 9 pm to 7 am**	**FAA Day-Night Sound Level (L_{dn})**
CP-1: Gilman & A Street	60	57	59	57	64
CP-2: Congress & Weymouth Street	61	57	61	57	65
CP-3: Wescott & Crescent Street	57	54	56	54	61
CP-4: Ellsworth & Charles Street Ext.	57	55	56	55	62
CP-5: Bowdoin & Chadwick Street	52	48	51	48	56
CP-6: West Promenade & West Street	57	55	56	56	63

Maine DEP Average Hourly L_{Aeq} – Arithmetic average of hourly equivalent sound levels (Hourly L_{Aeq}) for daytime (7 am to 7 pm) and nighttime (7 pm to 7 am).

City of Portland Average Hourly L_{Aeq} – Same as Maine DEP Average Hourly L_{Aeq} except for different daytime (7 am to 9 pm) and nighttime (9 pm to 7 am) periods.

FAA Day-Night Sound Level – The 24-hour equivalent sound level calculated by adding 10 dBA to hourly equivalent sound levels between 10 pm and 7 am.

Other site selection criteria evaluated by Maine Medical Center include availability of flight paths over transportation, industrial and commercial corridors, and access to helipad approaches to maximize safe operation in prevailing wind conditions; noise and exhaust impact on hospital facilities, internal access to emergency/operating facilities, compliance with FAA siting and safety criteria, construction schedule, cost and aesthetics.

5.0 NOISE MITIGATION

As described in Section 4.0, MMC has made efforts to locate the helipad and establish flight paths to minimize noise impact on residential areas. The following describes additional noise mitigation measures that have been evaluated by RSE.

5.1 Aircraft Certification & Flight Procedures

LifeFlight of Maine is a full partner in operational noise mitigation and follows noise abatement procedures as set forth in the *Fly Neighborly Guide* published by the Helicopter Association International. These procedures are consistent with advisory circular AC 91-66, Noise Abatement for Helicopters, developed by the Federal Aviation Administration (FAA), which provides guidelines for noise reduction when operating helicopters. The Helicopter Association International enhanced these guidelines as part of its *Fly Neighborly Guide*.

Specific provisions require pilots to maintain as high an altitude as possible on approach and as directed by air traffic control at the Portland Jetport. Final approach to the helipad is at a steep 12-15 degree angle to shorten the approach and flight time near the ground to lessen helicopter noise. Once on the helipad, pilots will generally spool down the aircraft (cooling the turbines for two minutes), or slow the rotors down, to either pick up or deliver the medical crew and patient. Helicopter sound levels decrease during the spool-down cycle and will drop by 10 dBA within 30 seconds after landing on the helipad. When departing, pilots use the best rate of climb (four to eight degree angle) from the helipad and follow approved flight paths until attaining a minimum altitude of 500 feet.

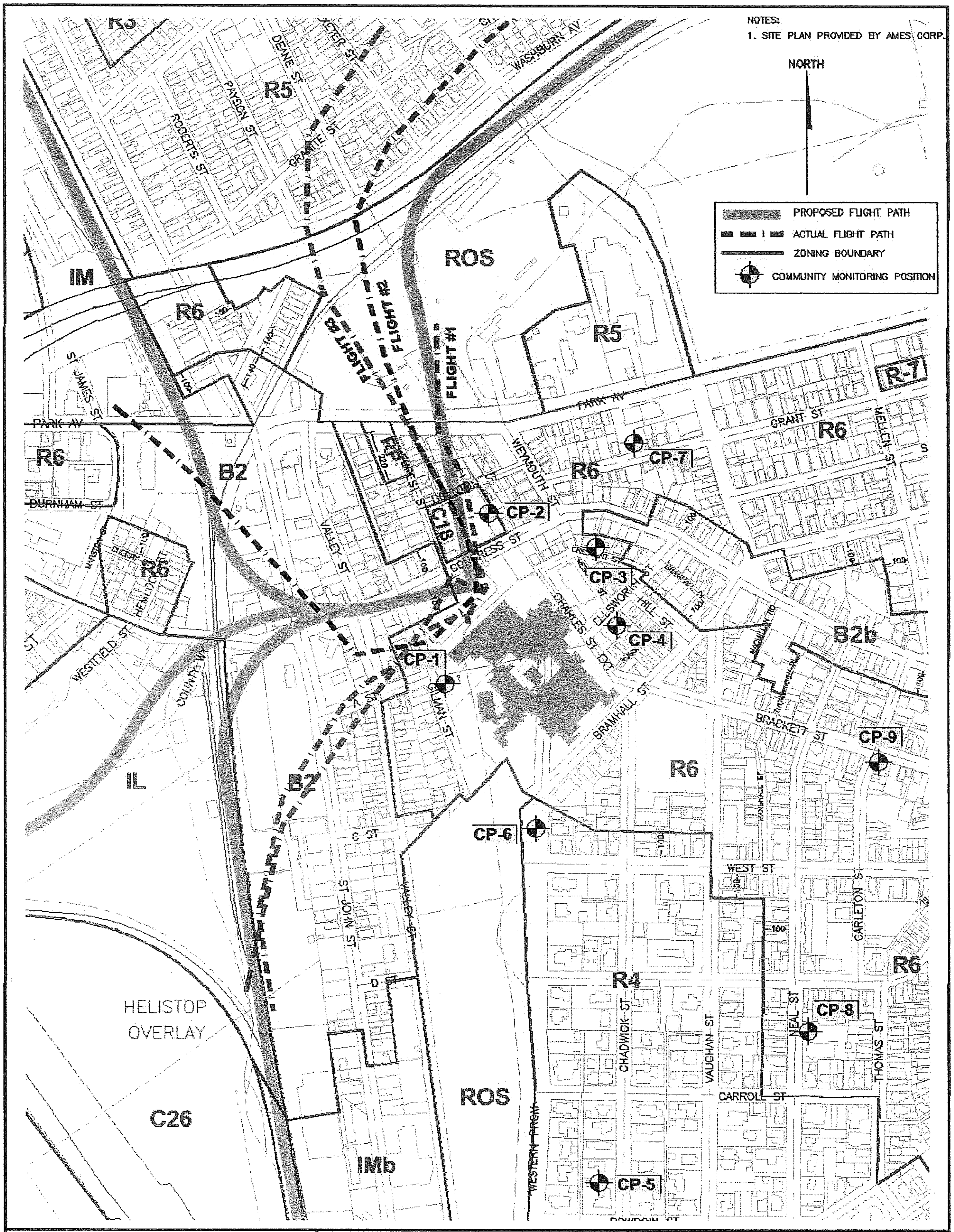
The FAA prescribes noise standards for certification of aircraft, including helicopters, in 14 CFR Part 36 (Noise Standards: Aircraft Type and Airworthiness). In order to receive certification, the aircraft manufacturer must demonstrate compliance with applicable takeoff, flyover, and approach noise levels of Part 36. More stringent noise limits apply to aircraft certifications after March 1986. Helicopters that demonstrate compliance with established noise limits meet the criteria for Stage 2 helicopters.

The specific aircraft currently used by LifeFlight of Maine are 1991 Agusta A-109C helicopters, which have a maximum takeoff weight of 5,997 pounds. RSE understands that the Agusta A-109C has been measured and certified in accordance with 14 CFR 36 and is a Stage 2 helicopter. The aircraft also complies with limits set by the International Civil Air Organization (ICAO), which are substantially equivalent to the applicable sections of 14 CFR 36. Sound levels measured for the Agusta A-109C are 2 to 5 dB below the ICAO limit.

5.2 Flight Testing

LifeFlight of Maine conducted flight testing in order to measure helicopter sound levels likely to be generated during medical flights. LifeFlight conducted flight testing at Maine Medical Center on September 13, 2003. The primary objectives in Portland were to simulate helipad flight operations for

FIGURE 1 VICINITY SITE PLAN



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MAINE MEDICAL CENTER
VICINITY SITE PLAN
PORTLAND, MAINE

DWG NO.: VSP-01
PROJECT: 010120
DRWN: RHM
CHECK: RSB
SHEET: 1 OF 1
REV: 1
DATE: 4-14-04
APP'D:

observation by local residents and to monitor resulting community and hospital sound levels. Monitoring results of the flight tests help to quantify sound levels as observed by the residents. Further, the results provide a basis for validating the noise prediction model at various receiver sites. Monitoring procedures, instrumentation and results from flight testing at Maine Medical Center can be found in *Community And LifeFlight Helicopter Sound Level Study* by RSE dated April 15, 2004.

Flight testing at Eastern Maine Medical Center was conducted in 1998 at the former helicopter landing site in an open parking lot to quantify helicopter noise during takeoff and landing procedures. In addition, measurements of sound level directivity were taken of the helicopter while hovering above the landing site.

RSE worked with LifeFlight personnel to establish the timing and sequence of takeoff and approach procedures when most of the noise associated with helipad operations will occur. Test flights were conducted to simulate the takeoff and approach of a typical medical flight from the proposed helipad. One objective of the flight testing was to monitor sound levels likely to be generated during future operation of the proposed helipad. Pilots followed standard operating procedures for noise avoidance and reduction as established by LifeFlight in accordance with the *Fly Neighborly Guide*.

The duration of *takeoff* (from cold startup to fly away) was approximately five minutes (5:00) resulting in an L_{Aeq} of 86.1 dBA at approximately 200 feet from the landing site and flight path. The time from startup to liftoff was 3:45 (mm:ss), or 75% of the time required to complete the takeoff sequence. The approach and landing sequence took approximately four minutes (4:00) resulting in an L_{Aeq} of 85.5 dBA. The period from touchdown to shutdown was 2:00, or 50% of the time required to complete the approach and landing sequence. The overall L_{Aeq} for the takeoff and approach for a round trip flight was 85.8 dBA for a period of nine minutes (9:00). Of these nine minutes, the amount of time spent on the helipad was 5:45, or 64% of the total time that the helicopter operated on or in very close proximity to the helipad.

Octave band and directional sound levels were measured with the helicopter hovering above the ground-level landing site. While hovering, the helicopter rotated its position so that sound level readings could be taken at eight compass points. The L_{Aeq}s at various angles ranged from 88 to 95 dBA. Octave band sound levels were measured at 200 feet from the left side of the hovering aircraft.

Sound instrumentation used for flight testing at Eastern Maine Medical Center consisted of a Larson Davis 812 Integrating Sound Level meter equipped with a Bruel & Kjaer 4155 microphone, and a B&K 2231 Precision Sound Level Meter equipped with a B&K 4155 microphone. A Bruel & Kjaer 1625 Octave Band Filter was used to record octave band sound levels from the helicopter.

5.3 Noise Model

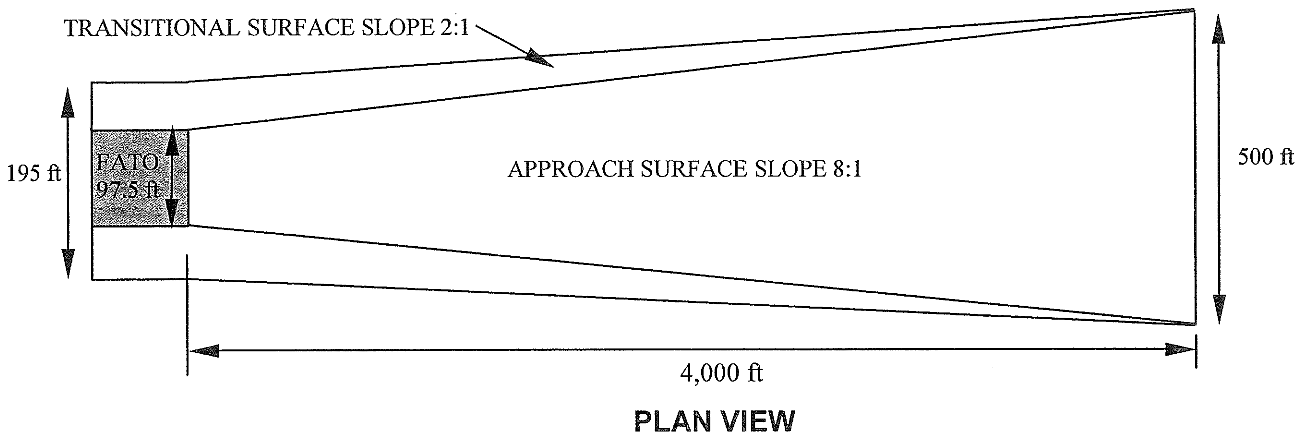
RSE completed a study of future sound levels associated with operation of the proposed helipad at MMC. This analysis consisted of monitoring helicopter test flights, developing a sound level prediction model for MMC, and evaluating various noise mitigation options.

In order to estimate future sound levels at surrounding land uses, RSE developed a sound level prediction (noise) model for Maine Medical Center. The noise model was developed using the Computer Aided Noise Abatement (CADNA) software program by DataKustik to map terrain and existing structures in three-dimensions, locate the helipad and other components of the proposed Phase I expansion, define helicopter sound levels, and calculate outdoor sound propagation to surrounding land uses. Distances and elevations for use in the model were imported from topographic site plans prepared by The Ritchie Organization and Sebago Technics.

converges at the 500-foot width point of the approach surface. The slope of the transitional surface is 2 to 1.

The following diagram (Figure 2) shows a layout of the FATO, Safety Area, Approach Surface, and Transitional Surface for one approach path of the proposed helipad.

FIGURE 2 – Helipad Safety and Approach Zones



The second approach from the west is nearly perpendicular to the approach from the north, which provides additional restrictions from those shown in Figure 2. The helipad safety and approach zones restrict the location of potential structures near the helipad and consequently limit opportunities for additional noise mitigation. The FAA restrictions moved the helipad further west of the new elevator tower resulting in additional noise reduction due to existing and proposed structures.

5.4.2 Barrier Options

Placing effective noise barriers on the existing garage within these constraints would require a combination of horizontal, sloped and vertical barriers. Barrier analysis began with some "oversized" structures that would not be practical to construct but would provide noise reduction. Next, the barriers were optimized to reduce their size as much as possible yet still achieve meaningful noise reduction from helipad operations.

Various barrier design and mitigation options were compared with sound levels expected from the helipad design that was the outcome of the site selection process. For each case, the noise source was located at the north edge of the pad (helicopter facing MMC) and the noise source located at the center of the helipad (helicopter facing both north and south). Noise barriers were modeled as sound absorbing and the helipad surface as reflective.

When considering noise mitigation options, surrounding buildings were modeled as reflective surfaces and then compared to buildings with absorptive surfaces. This comparison showed no significant change in community sound levels due to reflection of sound waves from MMC buildings.

The following model cases were selected to represent the extensive options modeled as part of the mitigation analysis:

Case 001 Existing Site Conditions Plus the Proposed Helipad and New Elevator

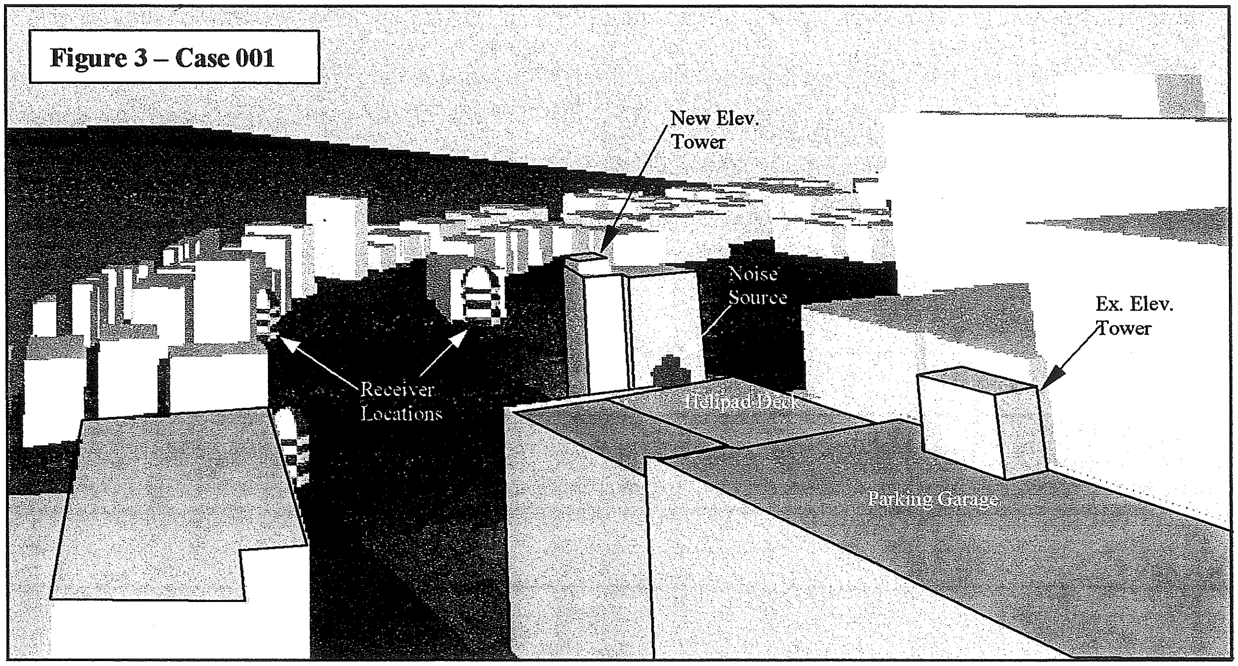


Figure 3 – Case 001

Case 002 Helipad with Construction of the Phase I Expansion

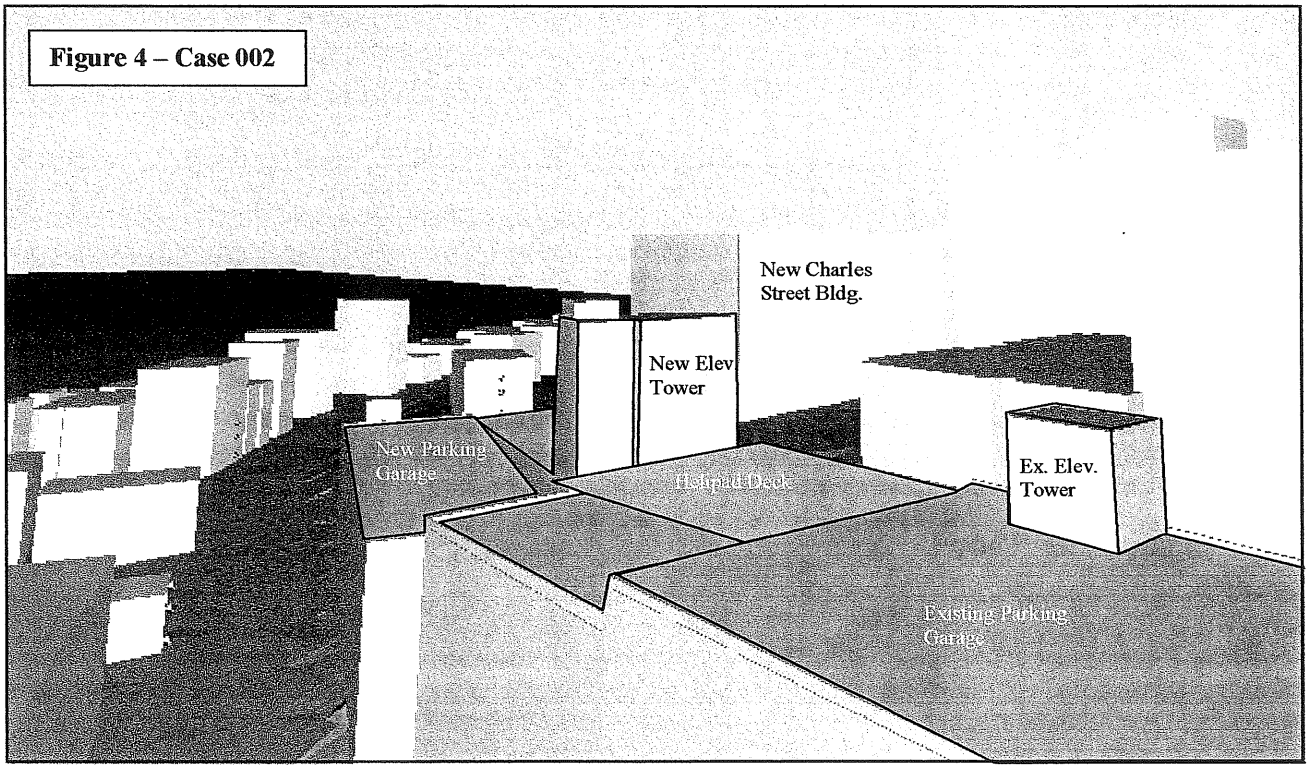


Figure 4 – Case 002

Case 003 Helipad with Phase I Expansion (Case 002) plus Sloped and Vertical Barriers

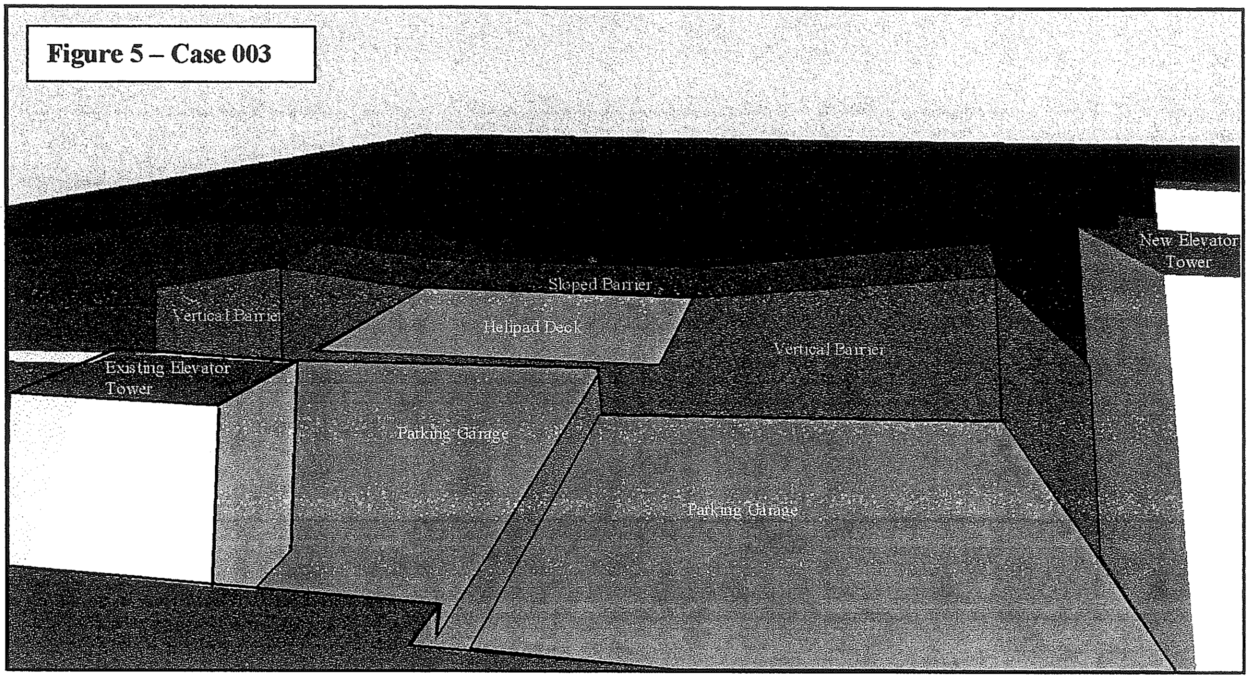


Figure 5 – Case 003

Case 004 Helipad with Phase I Expansion (Case 002) plus Sloped Noise Barriers

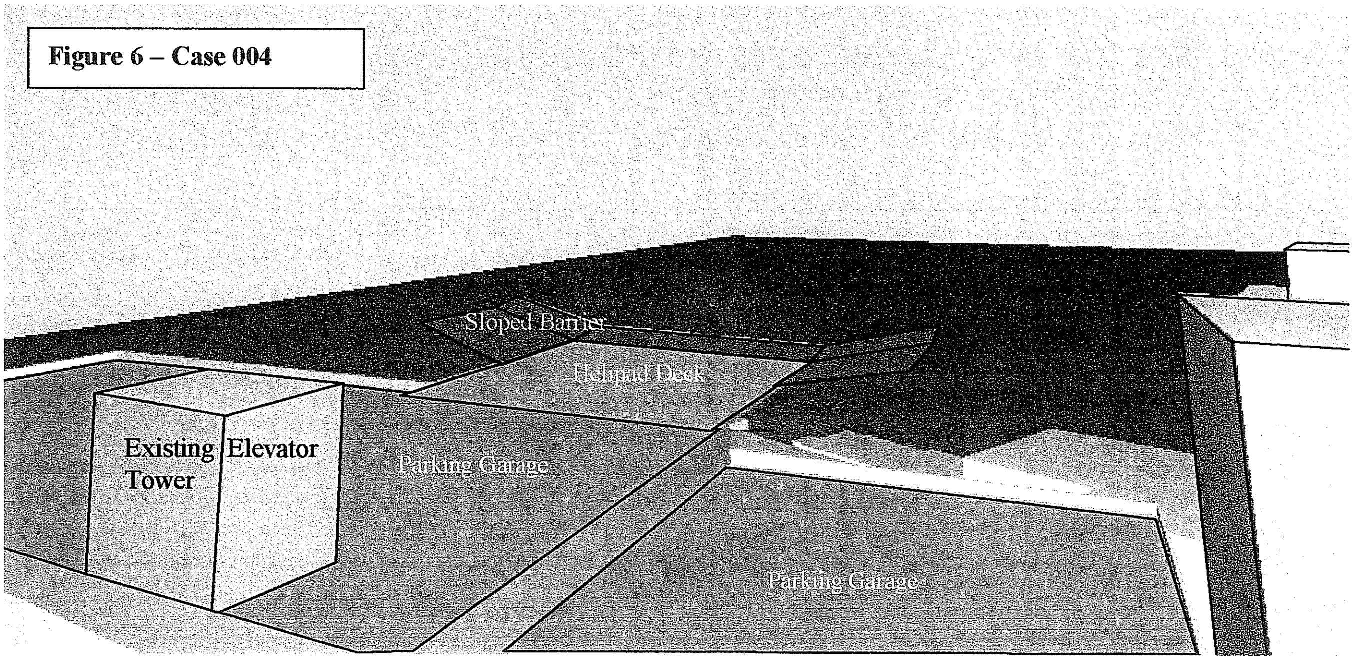


Figure 6 – Case 004

5.5 Mitigation Sound Level Estimates

Comparing Cases 001 and 002 shows the change in sound levels at the community monitoring positions that result from construction of the Charles Street Building. The following Table 2 provides this comparison:

Table 2
Helipad Sound Levels (dBA)
Case 001 vs Case 002

Receiver Position	Ht. Above Ground	Case 001 Center	Case 002 Center	dBA Change
CP-1	5	71	71	0
CP-2	5	71	71	0
CP-3	5	67	67	0
CP-4	5	75	56	-19
CP-6	5	54	54	0
CP-7	5	59	59	0

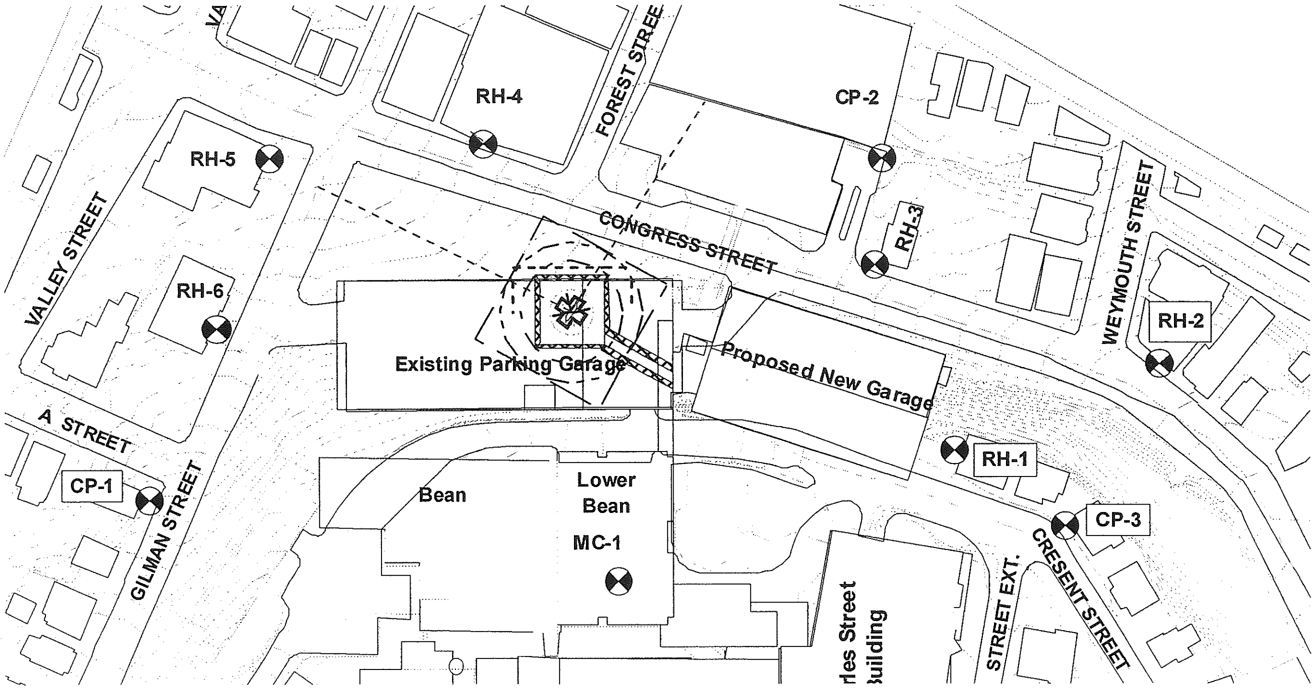
As expected, construction of the Charles Street Building significantly reduces sound levels in the vicinity of Position CP-4, Ellsworth Street and generally in a southeasterly direction.

The following Table 3 provides a comparison of Case 002 sound levels with the helicopter facing south toward MMC and with the helicopter facing north toward across Congress Street. The receiver positions presented in Table 3 represent the nearest residential properties to the existing parking garage and are shown on Figure 7.

Table 3
Helipad Sound Levels (dBA)
Case 002 North vs Case 002 South

Receiver Position	Ht. Above Ground (ft)	Case 002 Facing South	Case 002 Facing North	dBA Change
RH-1	5	79	73	-6
	16	79	73	-6
	24	79	73	-6
RH-2	5	78	78	0
	16	81	77	-4
	24	81	80	-1
RH-3	5	84	76	-8
	16	83	80	-3
	24	84	82	-2
RH-4	5	87	76	-11
	16	89	77	-12
	24	86	78	-8
RH-5	5	82	79	-3
	16	83	80	-3
	24	84	80	-4
RH-6	5	69	68	-1
	16	69	69	0
	24	70	70	0

FIGURE 7 - Noise Model Receiver Positions



Model estimates show sound level reductions up to 12 dBA with the helicopter operating on the pad facing north and the tail toward the hospital. This landing configuration allows the helipad and parking garage to block noise in the direction of residential land uses to the north. Further, the largest reductions occur at receivers where the highest helipad sound levels were predicted. This is a significant reduction considering that the helicopter spends most of its time operating on the pad when in close proximity to the hospital. Based on prevailing winds, RSE understands that the helicopter will normally land facing north with its tail rotor toward the hospital. With the tail toward the hospital the increase in sound levels at the hospital is negligible (less than 0.5 dBA).

The following comparison shows the additional noise reduction that could be achieved with implementation of the noise mitigation measures evaluated as model Case 003. In addition to construction of the Phase I expansion, Case 003 adds large vertical and sloped barriers to the helipad and the top of the existing garage (See Figure 5). The vertical barriers wrap around three sides of the helipad and range in height from 19 feet west of the helipad to 26 feet east of the helipad. The sloped barriers extend 20 feet north from the edge of the helipad at a slope of 8 to 1, following the approach surface. Table 4 compares helipad sound levels from Case 002 (Phase I expansion) and Case 003 (Phase I expansion plus vertical and sloped barriers).

Table 4
Helipad Sound Levels (dBA)
Case 002 (Phase I Expansion) vs Case 003 (Phase I Expansion Plus Vertical and Sloped Barriers)

Receiver Position	Ht. Above Ground (ft)	Case 002 Facing South	Case 003 Facing South	dBA Change	Case 002 Facing North	Case 003 Facing North	dBA Change
RH-1	5	79	68	-11	73	69	-4
	16	79	68	-11	73	69	-4
	24	79	68	-11	73	69	-4
RH-2	5	78	73	-5	78	72	-6
	16	81	74	-7	77	73	-4
	24	81	74	-7	80	74	-6
RH-3	5	84	74	-10	76	71	-5
	16	83	75	-8	80	71	-9
	24	84	75	-9	82	72	-11
RH-4	5	87	78	-9	76	72	-4
	16	89	79	-10	77	73	-4
	24	86	80	-6	78	73	-5
RH-5	5	82	76	-6	79	69	-10
	16	83	77	-6	80	70	-10
	24	84	77	-7	80	70	-10
RH-6	5	69	67	-2	68	68	0
	16	69	67	-2	69	69	0
	24	70	68	-2	70	69	-1

Table 4 shows that reductions of up to 11 dBA could be achieved with large barrier structures modeled as Case 003. Although such a barrier system may be viable for a ground-based helipad, RSE understands that the structural requirements alone would present a major obstacle to construction of this type of barrier system on the top of the existing garage. Further, the noise reductions for Case 003 with the helicopter facing south would provide no more attenuation than facing the aircraft to the north.

The final mitigation comparison shows the noise reduction that could be achieved with a more practical noise barrier system modeled as Case 004 (Helipad with Phase I Expansion plus Sloped Noise Barriers to the North, East and West) shown as Figure 6. The sloped barriers extend along the approach surface approximately 20 feet from the edge of the helipad toward the north and 26 feet along the approach surface to the east and west sides of the helipad. Table 5 provides a comparison of this case with Case 002 (Phase I Expansion).

This comparison shows noise reduction for Case 004 of up to 7 dBA with the helicopter facing south and up to 8 dBA while facing north. Again the noise model shows that rotating the aircraft to face north will result in greater noise reduction than implementing the Case 004 barrier (with the helicopter facing south). The additional reduction provided by the Case 004 barrier with the helicopter facing north will provide the most attenuation (8 dB) to receiver RH-5. Noise reduction at other receivers is less and overall sound levels are not significantly less than Case 002 facing north.

Table 5
Helipad Sound Levels (dBA)
Case 002 (Phase I Expansion) vs Case 004 (Phase I Expansion Plus Sloped Barriers)

Receiver Position	Ht. Above Ground (ft)	Case 002 Facing South	Case 004 Facing South	dB Change	Case 002 Facing North	Case 004 Facing North	dB Change
RH-1	5	79	79	0	73	73	0
	16	79	79	0	73	73	0
	24	79	79	0	73	73	0
RH-2	5	78	75	-3	78	78	0
	16	81	77	-4	77	77	0
	24	81	76	-5	80	80	0
RH-3	5	84	76	-8	76	73	-3
	16	83	77	-6	80	74	-6
	24	84	78	-6	82	81	-1
RH-4	5	87	80	-7	76	73	-3
	16	89	82	-7	77	74	-3
	24	86	84	-2	78	74	-4
RH-5	5	82	78	-4	79	71	-8
	16	83	79	-4	80	72	-8
	24	84	79	-5	80	72	-8
RH-6	5	69	67	-2	68	68	0
	16	69	67	-2	69	69	0
	24	70	68	-2	70	69	-1

Sound level contour maps of each model case can be found in Appendix I.

6.0 SUMMARY AND CONCLUSIONS

The primary objectives of the Noise Mitigation Study were to assist Maine Medical Center in selecting a site for the proposed helipad that would limit noise impact and to investigate additional noise control options to ensure that all practical noise mitigation was being incorporated into helipad design and operations. The helipad site and associated flight paths were carefully selected based on sound level estimates and community monitoring results to limit noise impact. Further refinement and analysis of the noise model estimates showed that the best mitigation option is to face the helicopter toward the north whenever possible during operation on or in close-range to the helipad. Due to prevailing winds the helicopter will typically land facing north.

Further, FAA design criteria were found to significantly restrict opportunities for additional mitigation using noise barriers. Through development and analysis of mitigation options, RSE found that an effective noise barrier, serving all areas not mitigated by new structures at MMC, would be too large to be practical for construction. Smaller noise barriers, such as Case 004, would provide no significant additional noise reduction to all areas not mitigated by new construction or by facing the helicopter northerly while on or in close range to the helipad.

During the Noise Mitigation Study, RSE also found that:

1. FAA design criteria were inherently aligned to the optimum location of the helipad on the existing garage for noise reduction from existing and proposed structures.

2. Because of area topography and the barrier effect of the existing garage, there was no significant sound level reduction from absorptive versus reflective surfaces of MMC buildings.

Tab 9

Traffic Impact Study
Proposed Expansion
Bramhall Campus
Portland, Maine

Prepared for:

Maine Medical Center
22 Bramhall Street
Portland, Maine, 04102

Revised April 2004

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Traffic Impact Study
Proposed Maine Medical Center Expansion
Bramhall Campus
Portland, Maine

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Appendix C

Executive Summary

The following Executive Summary is prepared for the reader's convenience, but is not intended to be a substitute for reading the full report.

Gorrill-Palmer Consulting Engineers, Inc. was retained by Maine Medical Center to complete a traffic impact study for a proposed Charles Street project planned at the Maine Medical Center (MMC) in Portland, Maine. The project includes the addition of a 192,000 s.f. building for the Obstetrics and Newborn Center, which would be bordered by reconfigured Charles, Ellsworth and Wescott Streets. Many of the functions for the new center already exist within the campus but are overcrowded and do not meet current industry layout standards. In addition, Maine Medical Center proposes to expand the existing ramp parking garage on the corner of Gilman Street and Congress Street to include an additional 512 parking spaces. The expansion will include a new driveway on Congress Street across from the Medical Office Building Garage. The location of the site is shown on Figure 1 in Appendix A.

The following is a summary of the major findings of the traffic study:

1) The proposed expansion is forecast to generate 19 and 25 new trip ends during the AM and PM peak hours, respectively. In addition, our office anticipates that 164 and 160 trip ends will be relocated from other areas on or near the campus to the proposed parking garage. As the campus will generate less than 100 net new trips ends, this project does not require a traffic movement permit from MDOT.

2) The level of service analyses show that all existing intersections in the study area are anticipated to operate at an acceptable level of service in the post development condition, with the exception of Congress Street at Gilman Street. However, the Gilman Street approaches have operated at low levels of service for some time, which is common for an unsignalized road entering to an arterial. This location is not forecast to warrant a traffic signal, and its close proximity to the signals at Valley Street result in gaps in traffic beyond those indicated in the level of service analysis.

   Delay is also anticipated for left turning traffic exiting the proposed garage drive, but this location is not anticipated to satisfy signal warrants. As with traffic exiting Gilman Street, nearby traffic signals will result in gaps in traffic that are anticipated to result in noticeably less delay for exiting traffic than the model indicates.

3) The crash data indicates that there are several high crash locations in or near the study area. Based on an analysis of these areas, Gorrill-Palmer Consulting Engineers, Inc. recommends the following:
   - Consideration of relocating the bus stop on the east side of St. John Street.
   - Placement of "ONLY" and left arrow pavement markings in the left lane of the northbound approach of St. John Street at Park Avenue. Installation of a

green arrow section under the green ball of the left signal head of both St. John Street approaches.

- Maintaining skip marks through intersection for left turn from St. John Street northbound onto Park Avenue westbound.
- That the broken white line be replaced by a solid white line to just beyond the Fairfield Inn driveway and two sets of thru-right and thru-left pavement marking arrows be installed in each lane approaching the Inn. In addition, a "ONE WAY" sign on Park Avenue west of St. John Street to alert drivers that this is a one-way road.
- Strict enforcement of parking regulations on Weymouth Street near Congress Street.
- Placement of signs on the eastbound approach of Congress Street in advance of Gilman Street warning of the merging lanes ahead.

4) The sight lines at the site drive exiting onto Congress Street are in excess of Maine DOT requirements provided parking is prohibited within 75 feet of the new garage entrance. Gorrill-Palmer Consulting Engineers, Inc. recommends that all plantings, which will be located within the right of way, not exceed 3 feet in height and be maintained at or below that height. Planned signage associated with the development should not interfere with sight lines. In addition, we recommend that during construction, when heavy equipment is entering and exiting into the site, that appropriate measures, such as signage and flag persons, be utilized in accordance with the Manual on Uniform Traffic Control Devices.

Based on these conclusions, it is the opinion of Gorrill-Palmer Consulting Engineers, Inc. that the existing traffic network can safely and effectively accommodate the traffic generated by the proposed development with measures taken as noted above.

I. *Existing Conditions*

The site for the proposed expansion is currently a paved lot on the corner of Charles Street, Ellsworth Street and Wescott Street. A 192,000 s.f. Obstetrics and Newborn Center is proposed as an expansion to Maine Medical Center with completion planned for 2007.

A 512 space-parking garage is also planned to be constructed as part of the project adjacent and to the east of the existing 1276 space garage at the corner of Gilman and Congress. Access to the proposed garage is planned from Congress Street opposite the Medical Office Building and an additional access provided on Crescent Street.

II. *Background Traffic Conditions*

Gorrill-Palmer Consulting Engineers, Inc. based the study on the following information:

- A concept plan prepared for Maine Medical Center by Sebago Technics.
- Crash data for the period 2000-2002 supplied by the Maine DOT.
- Turning movement volumes collected on Tuesday, July 29, 2003 from 6:30 – 8:30 AM and again on Tuesday, August 5 from 3:30 – 6:00 PM at the following locations:
  - Congress Street/Deering Avenue/Bramhall Street
  - Congress Street/Ellsworth Street
  - Congress Street/Forest Street
  - Congress Street/Valley Street
  - Congress Street/Saint John Street
- Turning movement volumes collected on Wednesday, July 30, 2003 from 6:30 – 8:30 AM and on Wednesday, August 6 from 3:30 – 6:00 PM at the following locations:
  - Park Avenue/Saint John Street
  - Park Avenue/Deering Avenue
- Trip generation counts collected on Thursday and Friday, February 26 and 27, 2004 from 7:30 – 8:30 AM and again at 4:30 – 5:30 PM at the following locations:
  - MMC Shuttle Lot off of St. John Street
  - Bramhall Street MMC Visitor's Lot

Predevelopment Traffic Volumes

The project is expected to be complete in the year 2007. The year 2007 predevelopment design hour volumes were determined utilizing the following methodology:

- The raw turning movement volumes were seasonally adjusted for a Group I arterial using information furnished by the Maine DOT to reach the estimated 30th highest hour.
- Volumes were annually adjusted by two percent per year, based on previous studies in the area and historic count data published by Maine DOT.
- Gorrill-Palmer Consulting Engineers, Inc. contacted the City of Portland to determine if any other projects, either in the approval process or under construction, would influence volumes within the study area. According to City, a proposed congregate housing facility is anticipated at the end of Frederic Street. However, traffic from this project is minimal, and has been included in the background growth. In addition, several projects are planned for the future, which would reduce traffic volumes in the study area. A new connector road is proposed to run from I-295 to the traffic circle at the intersection of St. John Street and Commercial Street. This new road will allow vehicles to get from I-295 to Commercial Street and the Casco Bay Bridge without having to use Congress Street, Park Street or St. John Street. This should significantly reduce volumes along these corridors. In addition, Mercy Hospital is proposing to relocate its entire campus to Commercial Street west of the Veterans Memorial Bridge. The hospital will be accessible from the new connector road, therefore, its traffic will no longer need to use the Congress Street and St. John Street corridors. Both of these projects are anticipated to reach completion after the expansion of the Maine Medical Center's Bramhall Campus. Therefore, the reductions in traffic have not been included in the predevelopment volumes although they are anticipated to reduce future traffic volumes in the study area.

The raw volumes shown on Figures 2 and 3 of Appendix A were seasonally and annually adjusted to reflect anticipated 2007 predevelopment traffic volumes on Figures 4 and 5 of Appendix A for the AM and PM peak hours, respectively.

Crash Information

Gorrill-Palmer Consulting Engineers, Inc. examined the High Crash Locations from Maine DOT for the period of 2000 to 2002, the most recent period available.

In order to evaluate whether a location has a crash problem, Maine DOT uses two criteria to define a High Crash Location (HCL). Both criteria must be met in order to be classified as an HCL.

1. A critical rate factor of 1.00 or more for a three-year period. (A Critical Rate Factor {CRF} compares the actual crash rate to the rate for similar

intersection in the state. A CRF of less that 1.00 indicates a rate of less than average) and:

2. A minimum of 8 crashes over a three-year period.

Based on the published history, the following locations within the study area were determined to be High Crash Locations:

Maine DOT High Crash Locations: 2000-2002

Node	Location	# of Crashes	CRF
08991	Congress Street/Gilman Street	15	1.49
07245	Congress Street/Weymouth Street	8	1.00
07187	Park Avenue/ St. John Street	34	1.01
07181	St. John Street/ A Street	10	1.28
7187-7188	Park Ave from St. John to Marston	9	1.13
7181-7182	St John from A to Congress	16	2.57
7182-7187	St John from Congress to Park	38	3.03

The Maine DOT crash printouts as well as the collision diagrams can be found in Appendix C. A discussion of each location follows:

St. John Street at A Street

This intersection is a high crash location with a critical rate factor of 1.28 and 10 collisions occurring during the years 2000-2002. Based on the collision diagram included in Appendix C, there are two apparent collision types at this location. The first type of collision occurs when an oncoming vehicle strikes a pedestrian attempting to cross from Union Station Plaza to A Street at night. Lighting in this location is poor at night and no crosswalks or pedestrian crossing signs exist. This location has been reviewed by the Portland Crosswalk Committee and found to be an appropriate location for pedestrians to cross therefore Gorrill-Palmer Consulting Engineers, Inc. recommends installation of signs directing pedestrians to cross St. John Street at the Congress Street traffic signal. The second type of collision occurs when vehicles crossing between Union Station Plaza and A Street collide with vehicles going straight on St. John Street. There was no pattern involving any one particular movement. The remaining collision was a rear-end collision and involved a driver under the influence of prescription drugs.

St. John Street from A Street to Congress Street

This location is an HCL with a critical rate factor of 2.57 and 16 collisions occurring during the years 2000-2002. Based on the collision diagram included in Appendix C, there are three apparent collision types at this location. The first type of collision occurs when vehicles exiting Union Station Plaza collide with vehicles on St. John Street. There were four of these collisions with no apparent correctable conditions. The second type of collision occurs when vehicles turning into a driveway collide with other vehicles. Out of the four collisions of this type, three occurred at the D'Angelo's driveway. Vehicles making a right turn from the inner lane into the

D'Angelo's driveway caused two of these collisions and the third was a southbound rearend. Clear pavement markings would address the improper turns. The provision of a more visible sign for D'Angelo's may reduce the collisions occurring with vehicles making the right turn from the inner lane. The third type of collision occurred when vehicles heading south on Saint John Street stopped for pedestrians crossing from Union Station Plaza and were subsequently rear-ended. As mentioned above, signs should be placed to direct pedestrians to cross at Congress Street. The remaining collisions are random in nature and do not indicate a collision pattern.

St. John Street from Congress Street to Park Avenue

This location is an HCL with a critical rate factor of 3.03 and 38 collisions occurring during the years 2000-2002. Based on the collision diagram included in Appendix C, there are three apparent collision types at this location. The first type of collision occurs when vehicles making a left turn out of a driveway collide with vehicles going straight on St. John Street. Three such collision occurred at Amato's, three occurred at McDonald's, three occurred at the Tire Center, six occurred at Dunkin' Donuts, and one occurred at Lang's Express. The second collision type occurs when vehicles making a left turn into a driveway collide with oncoming traffic or are rear-ended by a following vehicle. Three such collisions occurred at Amato's, one occurred at McDonald's, and three occurred at Dunkin' Donuts. Traffic volumes are high on St. John Street during peak hours and few adequate gaps in traffic exist to allow for a left turn. Additionally several collisions resulted from stacked traffic in one lane blocking the view to turning drivers of flowing traffic in the second lane. These could be addressed by restricting left turns. The third type of collision occurs when vehicles stopping or slowing for a bus at the bus stop on the eastern side of St. John Street are rear-ended by following vehicles. Consideration should be given to relocating the bus stop. The remaining collisions are random in nature and do not indicate an apparent collision pattern.

St. John Street at Park Avenue

This intersection is an HCL with a critical rate factor of 1.01 and 34 collisions occurring during the years 2000-2002. Based on the collision diagram included in Appendix C, there are three apparent collision types at this location. The first type of collision occurs when vehicles making the left turn from St. John Street onto Park Avenue collide with other vehicles making this same turn. Currently, there is a left turn lane and a left/thru lane on the northbound approach of St. John Street. Although skip marks are painted through the intersection, the lines have become faint and drivers often do not know in which lane they need to be. Gorrill-Palmer Consulting Engineers, Inc. recommends maintaining skip marks through the intersection. The second type of collision occurs when vehicles in the left turn only lane on the northbound approach of St. John Street decide to go straight and are struck by vehicles making a left-turn from the left/thru lane. Gorrill-Palmer Consulting Engineers, Inc. recommends installation of "ONLY" and left arrow pavement markings in the left lane. Additionally, a green arrow section should be added to the left signal head on both St. John Street approaches. The third type of collision occurs when vehicles stopped or slowing in traffic on the northbound approach of St. John Street are rear-ended by following vehicles. This type of collision is typical at intersections where a free-right turn exists.

Park Avenue from St. John Street to Marston Street

This location is an HCL with a critical rate factor of 1.13 and 9 collisions occurring during the years 2000-2002. Upon examination of the collision reports, it was found that one of the nine collisions actually occurred along St. John Street. The remaining eight collisions are shown on the collision diagram in Appendix C. As shown in the collision diagram, all of the eight collisions occur at the entrance to the Fairfield Inn. They all occur when a vehicle in the right hand lane attempts to make a left turn into the driveway and is struck by a vehicle going straight in the left lane. This driveway is in close proximity to the intersection of St. John Street and Park Avenue and drivers often do not know which lane to use to get to their hotel. Gorrill-Palmer Consulting Engineers, Inc. recommends that the broken white line be replaced by a solid white line to just beyond the Fairfield Inn driveway and two sets of thru-right and thru-left pavement marking arrows be installed in each lane approaching the Inn. In addition, a "ONE-WAY" sign should be posted along Park Avenue so that drivers know that this section of Park Avenue is a one-way road.

Congress Street at Weymouth Street

This location is an HCL with a critical rate factor of 1.00 and 8 collisions occurring during the years 2000-2002. Based on the collision diagram included in Appendix C, there are two collision types apparent at this location. The first type of collision occurs when vehicles turning from Congress Street onto Weymouth Street collide with vehicles parked illegally on Weymouth Street. Gorrill-Palmer Consulting Engineers, Inc. recommends strict enforcement of parking regulations on this street. The second type of collision occurs when vehicles waiting to make the left turn from Congress Street onto Weymouth Street are rear-ended by following vehicles. Congress Street could be re-stripped to allow a short left turn lane or by-pass lane. However this would require removal of approximately ten parking spaces and would increase speeds around the curve in Congress Street.

Congress Street at Gilman Street

This location is an HCL with a critical rate factor of 1.49 and 15 collisions occurring during the years 2000-2002. Based on the collision diagram included in Appendix C, there are four collision types apparent at this intersection. The first collision type occurs when vehicles turning left from Gilman Street onto Congress Street collide with vehicles going straight on Congress Street. There do not appear to be any specific contributing factors that could be addressed for these collisions. The second type of collision occurs when vehicles headed east on Congress Street and slowing in traffic are rear-ended by a following vehicle. The eastbound approach of Congress Street drops from two lanes to one lane immediately to the east of the intersection with Gilman Street, which leads to several rear-end collisions as vehicles merge. Gorrill-Palmer Consulting Engineers, Inc. recommends advance signage that Congress Street reduces to a single lane ahead.

III. *Trip Generation*

The current Bramhall campus consists of approximately 900,000 s.f. of hospital space (inpatient and outpatient) as well as medical office space. Much of the hospital space does not meet current industry standards. Therefore, the Obstetrics and Newborn Center is proposed largely to allow for some decompression of the campus. The facility is to be a total of 165,000 s.f. of space, with another 27,000 s.f. devoted to the mechanical penthouse. The expansion will allow for some increase in patient population, from 480 in 2003 to 490 in 2007, or approximately two percent.

New Trips for Obstetrics and Newborn Center

Our office utilized the Institute of Transportation Engineers (ITE) publication, *Trip Generation*, 7th Edition to determine the campus increase in trips from 480 to 490 patients. Our office referenced Land Use Code 610, Hospital, to determine the increase based on the increase of ten beds for the campus. The net increase is shown as follows:

Trip Generation from 480 to 490 Beds* Due to Hospital Expansion

LUC 610: Hospital**	Weekday	AM Peak Hour	PM Peak Hour	Saturday
480 Beds	16,087	921	1,205	10,099
490 Beds	15,758	902	1,230	10,310
Net Increase	329	19	25	211

*Occupied beds for the Bramhall campus.
**Based on the maximum observed rate in the ITE database to provide conservative results.

As can be seen from the above table, the addition of ten beds is anticipated to add an additional 19 and 25 trip ends for the AM and PM peak hours, respectively. This level of additional trip generation is lower than the 100-trip threshold triggering the need for an MDOT traffic movement permit.

Total Trips to Proposed Garage

To determine the total activity for the proposed garage, Gorrill-Palmer Consulting Engineers, Inc. completed trip generation counts on Thursday, February 26, 2004 at the MMC Shuttle Lot off of St. John Street. In addition, trip generation counts were completed at the Bramhall Street Visitor's Lot on Friday, February 27, 2004. According to Steven Hobart, Operations Manager for Security and Parking, these were representative of typical times for these lots. The trip generation rates were compiled for each lot and averaged to determine a rate for the proposed garage. These trip rates and generation are shown in the following table:

Trip Rates and Generation for Existing Lots and Proposed Garage

Location	AM Peak (7:30-8:30)		PM Peak (4:30-5:30)	
	Rate	Trips	Rate	Trips
Shuttle Lot (280 spaces)	0.429	120	0.279	78
Visitor's Lot (328 spaces)	0.287	94	0.445	146
Proposed Garage (512 spaces)	0.358	183	0.362	185

VIII. *Study Area*

For the purposes of this study, we have analyzed the following intersections:

- Congress Street/Deering Avenue/Bramhall Street
- Congress Street/Ellsworth Street
- Congress Street/Forest Street
- Congress Street/Valley Street
- Congress Street/Saint John Street
- Saint John Street/Park Avenue
- Park Avenue/Deering Avenue
- Congress Street/Gilman Street
- Congress Street/MOB Garage Access/Garage Driveway

IX. *Capacity Analysis*

Gorrill-Palmer Consulting Engineers, Inc. completed capacity analyses using Synchro 5, Traffic Signal Coordination Software. Levels of service rankings are similar to the academic ranking system where an 'A' is very good with little control delay and an 'F' represents very poor conditions. At an unsignalized intersection, if the level of service falls below a 'D', an evaluation should be made to determine if a traffic signal is warranted.

The following table summarizes the relationship between delay and level of service for a signalized intersection:

Level of Service Criteria for Signalized Intersections

Level of Service	Control Delay per Vehicle (sec)
A	Up to 10.0
B	10.1 to 20.0
C	20.1 to 35.0
D	35.1 to 55.0
E	55.1 to 80.0
F	Greater than 80.0

The following table summarizes the relationship between delay and level of service for an unsignalized intersection.

Level of Service Criteria for Unsignalized Intersections

Level of Service	Control Delay per Vehicle (sec)
A	Up to 10.0
B	10.1 to 15.0
C	15.1 to 25.0
D	25.1 to 35.0
E	35.1 to 50.0
F	Greater than 50.0

Gorrill-Palmer Consulting Engineers, Inc. based our analyses on the existing roadway configurations. The analyses were based on Figures 4 and 5 for the predevelopment scenario and Figures 10 and 11 for the post development scenario. The results of the capacity analyses are summarized as follows. The detailed analyses are included in Appendix B.

Level of Service for Congress Street at Bramhall/Deering - Signalized

Approach	2007 AM Peak Hour				2007 PM Peak Hour			
	Pre		Post		Pre		Post	
	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS
Bramhall NBL	34	C	34	C	14	B	14	B
Bramhall NBTR	20	C	20	B	12	B	12	B
Deering SB	19	B	19	B	39	D	39	D
Congress EBL	11	B	11	B	19	B	20	B
Congress EBTR	15	B	16	B	49	D	51	D
Congress WBL	7	A	7	A	14	B	14	B
Congress WBTR	6	A	6	A	15	B	16	B

Note: Signal splits and phases were optimized for both the pre and post condition.

Level of Service for Congress Street at Valley Street - Signalized

Approach	2007 AM Peak Hour				2007 PM Peak Hour			
	Pre		Post		Pre		Post	
	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS
Valley NBL	8	A	9	A	10	A	10	A
Valley NBTR	6	A	7	A	8	A	8	A
Congress EB	29	C	27	C	13	B	13	A
Congress WBLT	28	C	28	C	21	C	36	D
Congress WBR	13	B	13	B	6	B	7	A

Note: Signal splits and phases were optimized for both the pre and post condition.

Level of Service for Congress Street at St. John Street - Signalized

Approach	2007 AM Peak Hour				2007 PM Peak Hour			
	Pre		Post		Pre		Post	
	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS
St. John NB	26	C	26	C	20	B	20	B
St. John SB	19	B	20	B	21	C	22	C
Congress EBL	36	D	36	D	42	D	42	D
Congress EBTR	15	B	16	B	18	B	18	B
Congress WBL	39	D	45	D	38	D	46	D
Congress WBR	8	A	8	A	25	C	37	D

Note: Signal splits and phases were optimized for both the pre and post condition.

Level of Service for Park Avenue at St. John Street – Signalized

Approach	2007 AM Peak Hour				2007 PM Peak Hour			
	Pre		Post		Pre		Post	
	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS
St. John NBL	23	C	24	C	43	D	49	D
St. John NBLT	24	C	24	C	46	D	54	D
St. John NBR	4	A	4	A	8	A	8	A
St. John SBLT	56	E	62	E	40	D	43	D
St. John SBR	7	A	8	A	18	B	19	B
Park WBLT	26	C	27	C	44	D	46	D
Park WBR	7	A	7	A	4	A	4	A

Note: Signal splits and phases were optimized for both the pre and post condition.

Level of Service for Park Avenue at Deering Avenue - Signalized

Approach	2007 AM Peak Hour				2007 PM Peak Hour			
	Pre		Post		Pre		Post	
	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS
Deering NBL	18	B	18	B	23	C	23	C
Deering NBTR	17	B	18	B	23	C	24	C
Deering SBL	16	B	17	B	24	C	24	C
Deering SBTR	16	B	17	B	23	C	24	C
Park EB	15	B	15	B	15	B	15	B
Park WBLT	16	B	17	B	17	B	17	B
Park WBR	4	A	4	A	2	A	2	A

Note: Signal splits and phases were optimized for both the pre and post condition.

Level of Service for Congress Street at Forest Street - Unsignalized

Approach	2007 AM Peak Hour				2007 PM Peak Hour			
	Pre		Post		Pre		Post	
	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS
Forest SB	24	C	36	E	16	C	19	C
Congress EB	1	A	2	A	2	A	2	A
Congress WB	<1	A	<1	A	<1	A	<1	A

Level of Service for Congress Street at Gilman Street - Unsignalized

Approach	2007 AM Peak Hour				2007 PM Peak Hour			
	Pre		Post		Pre		Post	
	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS
Gilman NBL	63	F	>80	F	68	F	>80	F
Gilman NBR	18	C	24	C	16	C	17	C
Gilman SB	22	C	40	E	22	C	28	D
Congress EBTR	<1	A	<1	A	<1	A	<1	A
Congress WBTL	2	A	2	A	1	A	1	A

Level of Service for Congress Street at Site Drive - Unsignalized

Approach	2007 AM Peak Hour *				2007 PM Peak Hour *			
	Pre		Post		Pre		Post	
	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS
Existing Drive SB	13	B	14	B	20	C	25	C
Site Drive NBL	-	-	69	F	-	-	>80	F
Site Drive NBR	-	-	15	B	-	-	13	B
Congress EBL	8	A	8	A	9	A	9	A
Congress EBT	<1	A	-	-	<1	A	-	-
Congress EBTR	-	-	<1	A	-	-	<1	A
Congress WBL	-	-	10	A	-	-	9	A
Congress WBTR	<1	A	<1		<1	A	<1	A

* (-) indicates movements or lane groups that do not exist in the pre or post development condition.

As shown in the table above, all existing locations in the study area are anticipated to operate at acceptable levels of service, with the exceptions of Congress Street at Gilman Street as well as the garage drive at Congress Street. However, the Gilman Street approaches have operated at low levels of service for some time, which is common for an unsignalized road coming into a high-volume arterial. This location is not forecast to warrant a traffic signal, and the existing approach geometry on each leg of Gilman Street is appropriate to the volumes.

In addition, left turning traffic exiting the proposed garage will face potential delay. As with the traffic at Gilman Street, volumes do not warrant a traffic signal, and the garage exit volume is forecast to be only about one vehicle per two minutes.

Our office examined operations at the garage access to Congress Street with SimTraffic, and based on the simulation, the site is not forecast to experience delay as great as the unsignalized analysis indicates. This is due to the fact that gaps are created in traffic along Congress Street by signals to both the east and west of the driveway.

Based on the capacity analyses shown in the tables above, it is the opinion of Gorrill-Palmer Consulting Engineers, Inc. that the existing roadway network can accommodate the additional traffic generated by the proposed expansion.

X. *Sight Lines*

The Maine Department of Transportation has guidelines for driveway sight distances within an urban compact. These sight distances are as follows:

MDOT Standards for Sight Distance – Urban Compact

Posted Speed (mph)	Sight Distance
25	200
30	250
35	305
40	360
45	425
50	495

Gorrill-Palmer Consulting Engineers, Inc. has evaluated the available sight lines at the proposed driveway in accordance with Maine DOT standards.
The Maine DOT standards are as follows:

Driveway observation point:	10 feet off major street travel way
Height of eye at driveway:	3 ½ feet above ground
Height of approaching vehicle:	4 ¼ feet above road surface

The results of this sight line analysis exiting onto Congress Street are summarized in the following table:

Driveway Sight Line Evaluation

Direction	Posted Travel Speed (mph)	Recommended Sight Line (ft)	Actual Sight Line (ft)
Exiting onto Congress Street Looking:			
Left	25	200	>200*
Right	25	200	>200*

*Exceeds 200 ft if no on-street parking is nearby.

As shown, the sight lines for these locations exceed Maine DOT requirements. Our office recommends prohibiting on-street parking within 75 feet of the new entrance to improve sight lines and safety. Gorrill-Palmer Consulting Engineers, Inc. recommends that all plantings, which will be located within the right of way, not exceed 3 feet in height and be maintained at or below that height. Signage should not interfere with sight lines. In addition, we recommend that during construction, when heavy equipment is entering and exiting into the site, that appropriate measures, such as signage and flag persons, be utilized in accordance with the Manual on Uniform Traffic Control Devices.

XII. Conclusions

The following is a summary of the major findings of the traffic study:

1) The proposed expansion is forecast to generate 19 and 25 new trip ends during the AM and PM peak hours, respectively. In addition, our office anticipates that 164 and 160 trip ends will be relocated from other areas on or near the campus to the proposed parking garage. As the campus will generate less than 100 net new trips ends, this project does not require a traffic movement permit from MDOT.

2) The level of service analyses show that all existing intersections in the study area are anticipated to operate at an acceptable level of service in the post development condition, with the exception of Congress Street at Gilman Street. However, the Gilman Street approaches have operated at low levels of service for some time, which is common for an unsignalized road entering to an arterial. This location is not forecast to warrant a traffic signal, and its close proximity to the signals at Valley Street result in gaps in traffic beyond those indicated in the level of service analysis.

   Delay is also anticipated for left turning traffic exiting the proposed garage drive, but this location is not anticipated to satisfy signal warrants. As with traffic exiting Gilman Street, nearby traffic signals will result in gaps in traffic that are anticipated to result in noticeably less delay for exiting traffic than the model indicates.

3) The crash data indicates that there are several high crash locations in or near the study area. Based on an analysis of these areas, Gorrill-Palmer Consulting Engineers, Inc. recommends the following:

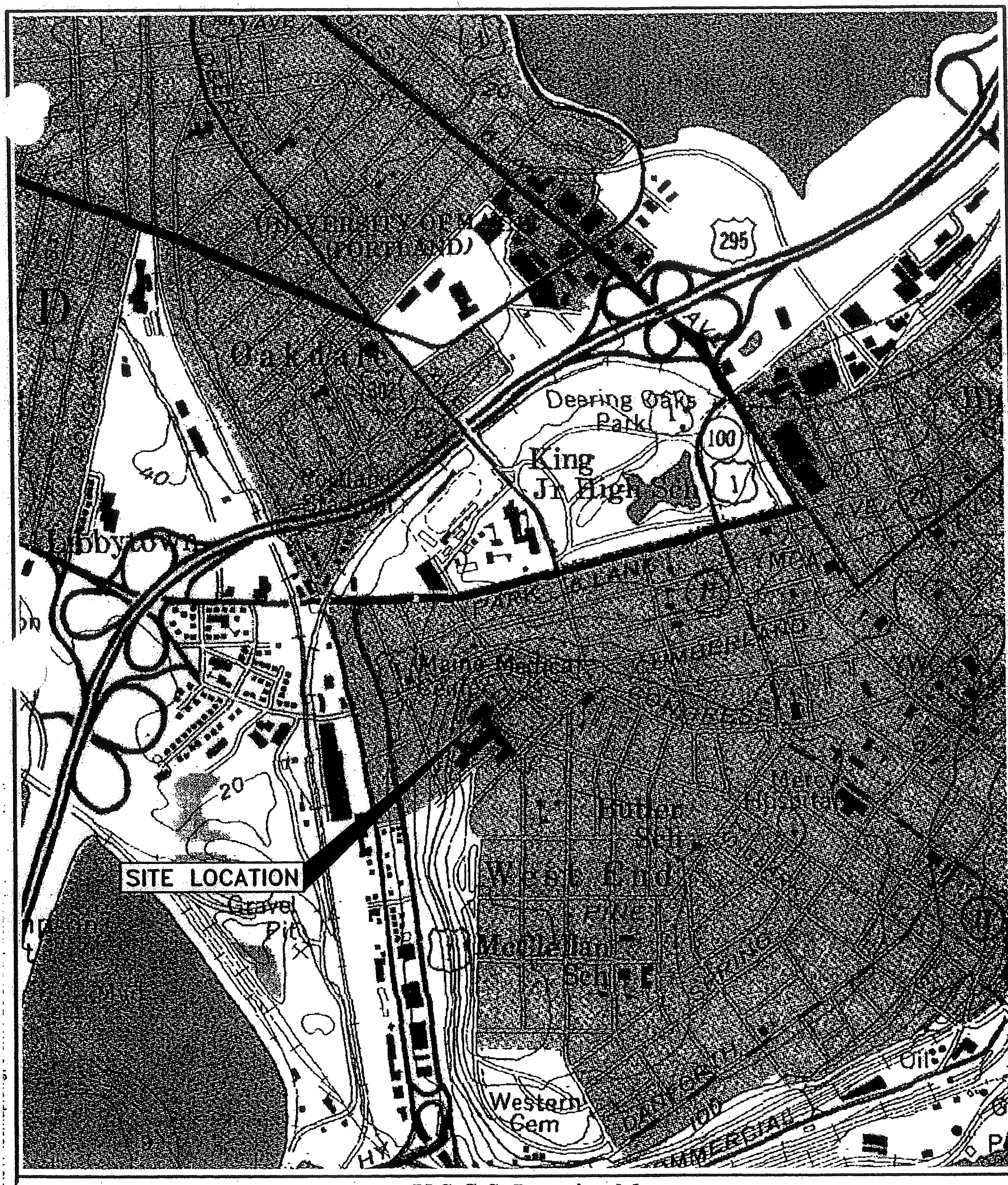
   - Consideration of relocating the bus stop on the east side of St. John Street.
   - Placement of "ONLY" and left arrow pavement markings in the left lane of the northbound approach of St. John Street at Park Avenue. Installation of a green arrow section under the green ball of the left signal head of both St. John Street approaches.
   - Maintaining skip marks through intersection for left turn from St. John Street northbound onto Park Avenue.
   - That the broken white line be replaced by a solid white line to just beyond the Fairfield Inn driveway and two sets of thru-right and thru-left pavement marking arrows be installed in each lane approaching the Inn. In addition, a "ONE WAY" sign on Park Avenue west of St. John Street to alert drivers that this is a one-way road.
   - Strict enforcement of parking regulations on Weymouth Street near Congress Street.
   - Placement of signs on the eastbound approach of Congress Street in advance of Gilman Street warning of the merging lanes ahead.

4) The sight lines at site drive exiting onto Congress Street are in excess of Maine DOT requirements provided parking is prohibited within 75 feet of the new garage entrance. Gorrill-Palmer Consulting Engineers, Inc. recommends that all plantings, which will be located within the right of way, not exceed 3 feet in height and be maintained at or below that height. Planned signage associated with the development should not interfere with sight lines. In addition, we recommend that during construction, when heavy equipment is entering and exiting into the site, that appropriate measures, such as signage and flag persons, be utilized in accordance with the Manual on Uniform Traffic Control Devices.

Based on these conclusions, it is the opinion of Gorrill-Palmer Consulting Engineers, Inc. that the existing traffic network can safely and effectively accommodate the traffic generated by the proposed development with measures taken as noted above.

Appendix A

Site Location Diagram
Turning Movement Diagrams



U.S.G.S. Location Map

Maine Medical Center - Portland, Maine

U.S.G.S. Portland-West, Maine-7.5 Minute Series (Topographic)

Design: JJB	**Date:** JAN 2004
Draft: DB	**Job No.:** 317
Checked: RCN	**Scale:** None
File Name: 317-LOCMAP.DWG	

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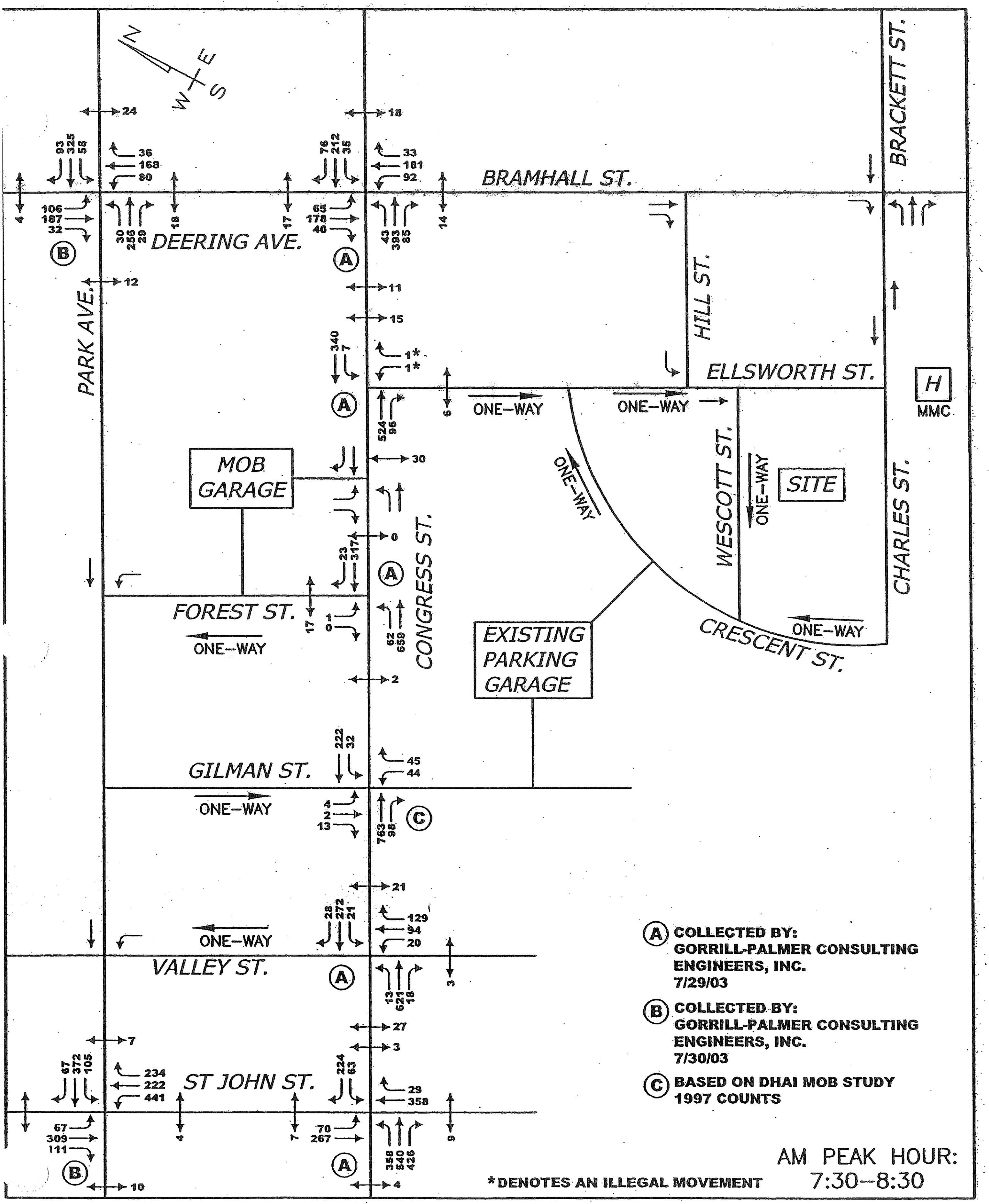
Figure
1



Ⓐ COLLECTED BY:
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7/29/03

Ⓑ COLLECTED BY:
GORRILL-PALMER CONSULTING ENGINEERS, INC.
7/30/03

Ⓒ BASED ON DHAI MOB STUDY
1997 COUNTS

*DENOTES AN ILLEGAL MOVEMENT

AM PEAK HOUR:
7:30–8:30

Design: MJM	Date: JAN 04
Draft: DB	Job No.: 317
Checked: RCN	Scale: NONE
File Name: 317-TRAF2.DWG	

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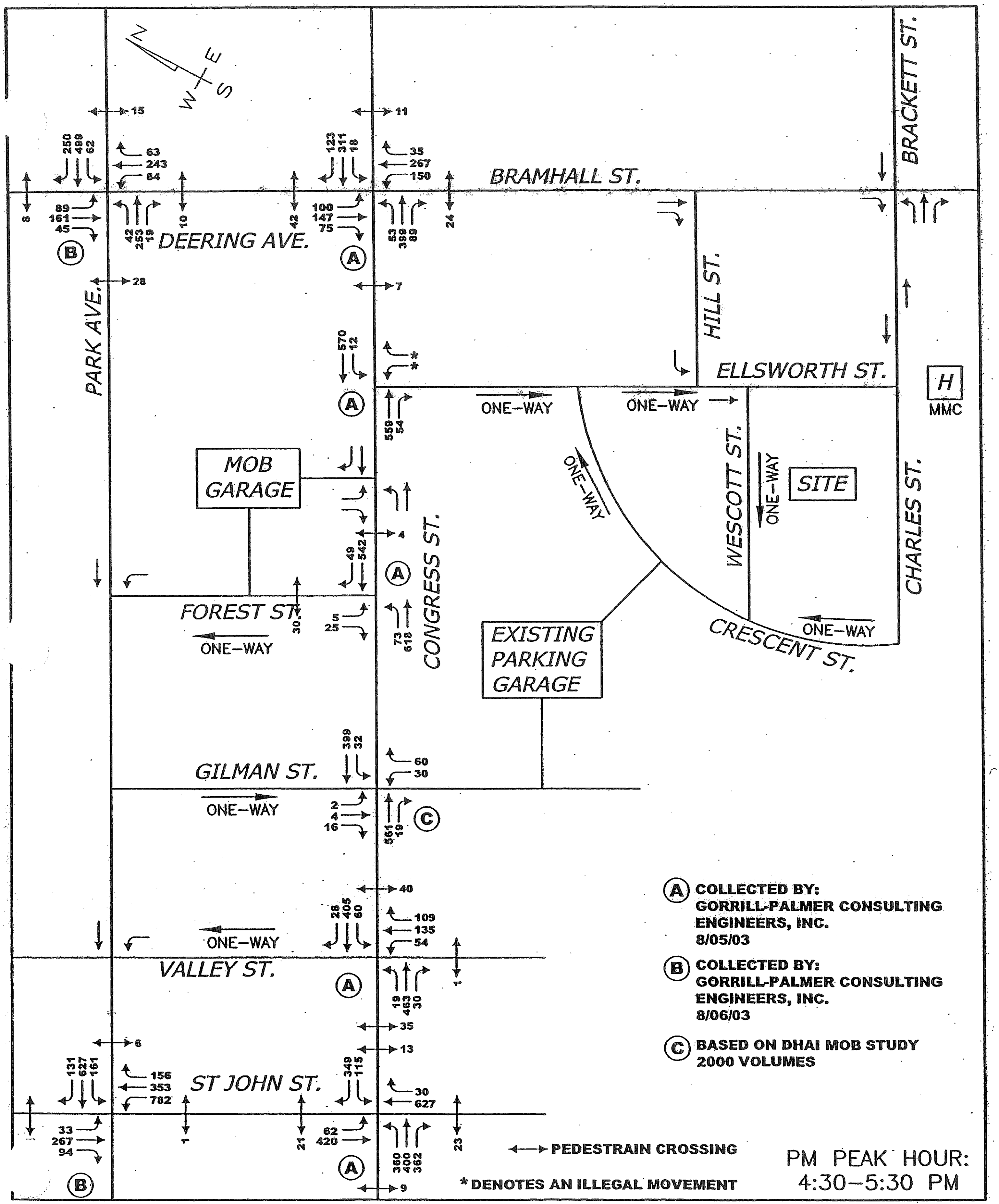
Drawing Name:
Raw Data

Project:
MAINE MEDICAL CENTER

Figure No.
2



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8/05/03

Ⓑ COLLECTED BY:
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8/06/03

Ⓒ BASED ON DHAI MOB STUDY
2000 VOLUMES

←→ PEDESTRAIN CROSSING

* DENOTES AN ILLEGAL MOVEMENT

PM PEAK HOUR:
4:30–5:30 PM

Design: MJM	Date: JAN 04
Draft: DB	Job No.: 317
Checked: RCN	Scale: NONE
File Name: 317-TRAF2.DWG	

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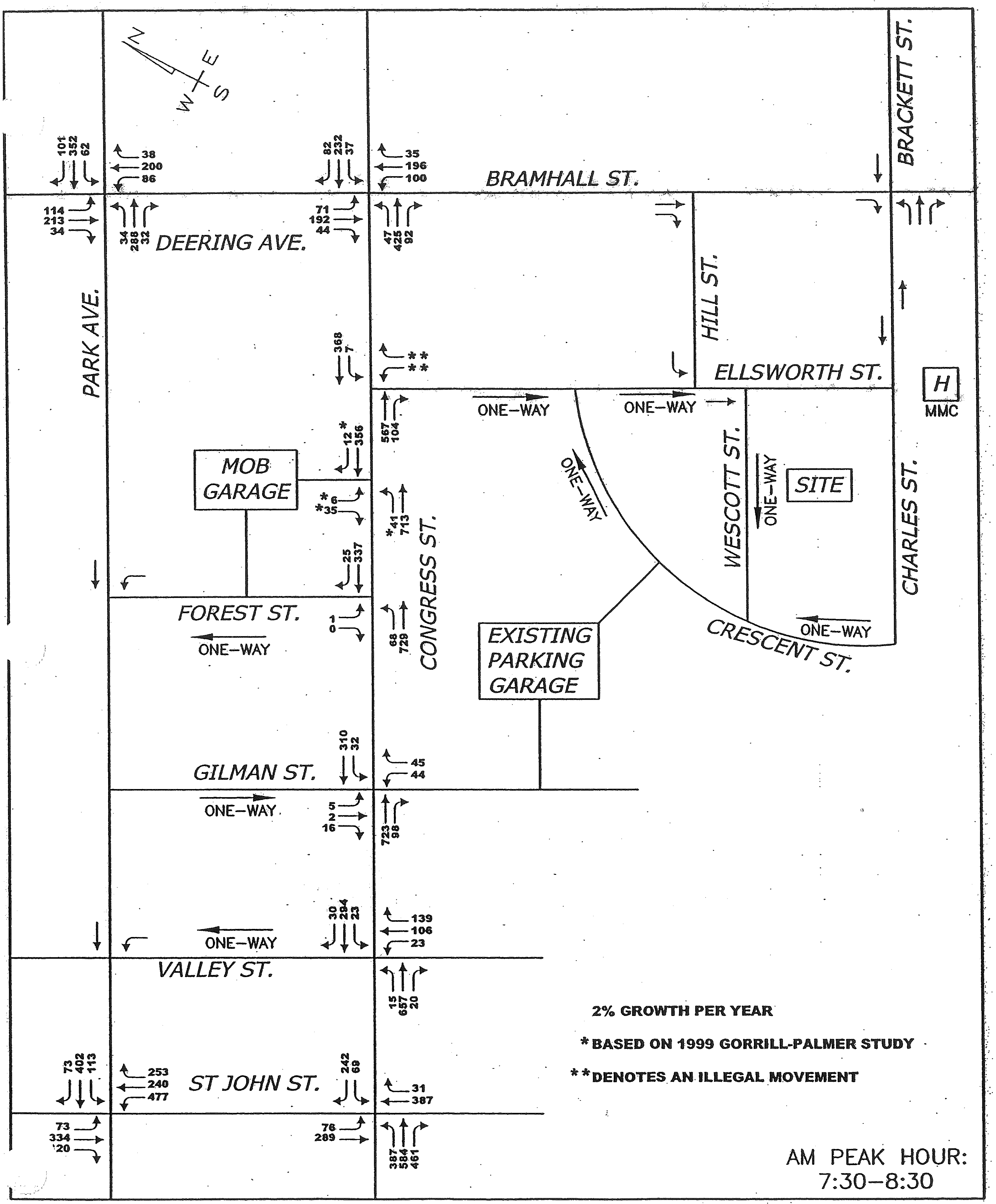
Drawing Name: Raw Data

Project: MAINE MEDICAL CENTER

Figure No. 3



2% GROWTH PER YEAR

* BASED ON 1999 GORRILL-PALMER STUDY

** DENOTES AN ILLEGAL MOVEMENT

AM PEAK HOUR:
7:30–8:30

Design: MJM	Date: JAN 04
Draft: DB	Job No.: 317
Checked: RCN	Scale: NONE
File Name: 317–TRAF2.DWG	

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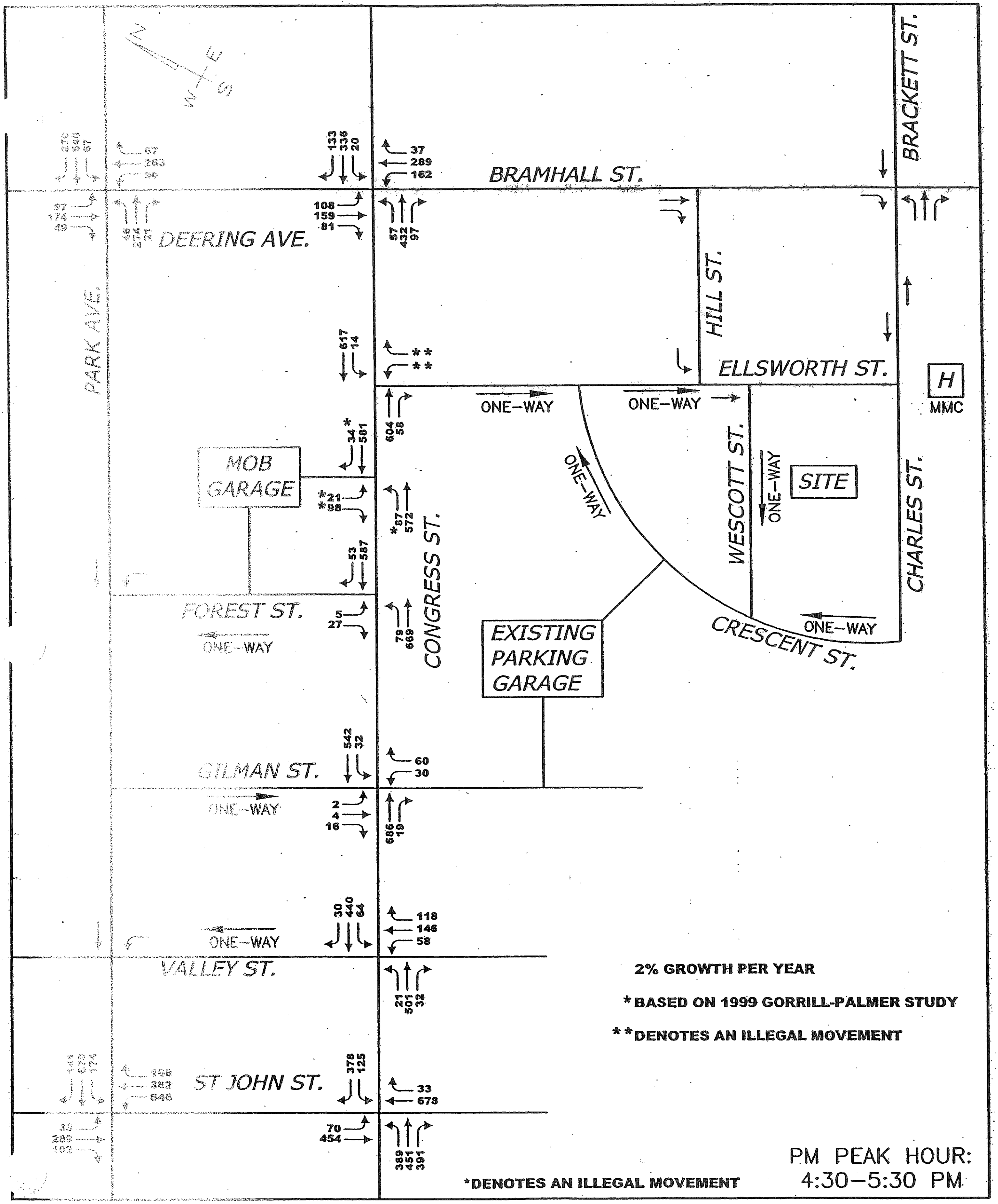
Drawing Name:
2007 Predevelopment Volumes

Project:
MAINE MEDICAL CENTER

Figure No.
4



2% GROWTH PER YEAR

*BASED ON 1999 GORRILL-PALMER STUDY

**DENOTES AN ILLEGAL MOVEMENT

*DENOTES AN ILLEGAL MOVEMENT

PM PEAK HOUR:
4:30–5:30 PM

Design: MJM	Date: JAN 04
Draft: DB	Job No.: 317
Checked: RCN	Scale: NONE
File Name: 317–TRAF2.DWG	

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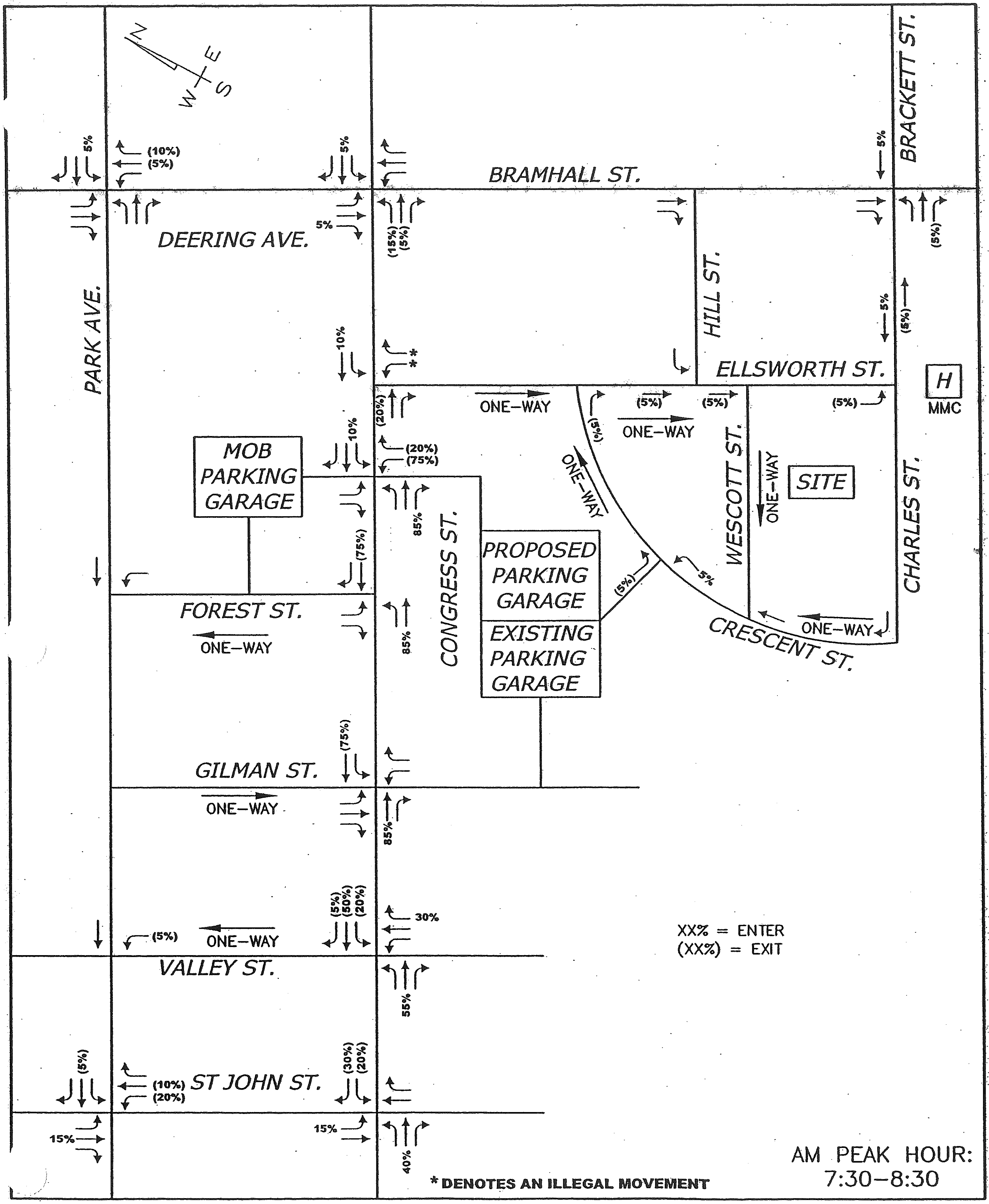
Drawing Name:
2005 Predevelopment Volumes

Project:
MAINE MEDICAL CENTER

Figure No.
5



Design: MJM
Date: JAN 04
Draft: DB
Job No.: 317
Checked: RCN
Scale: NONE
File Name: 317–TRAF2.DWG

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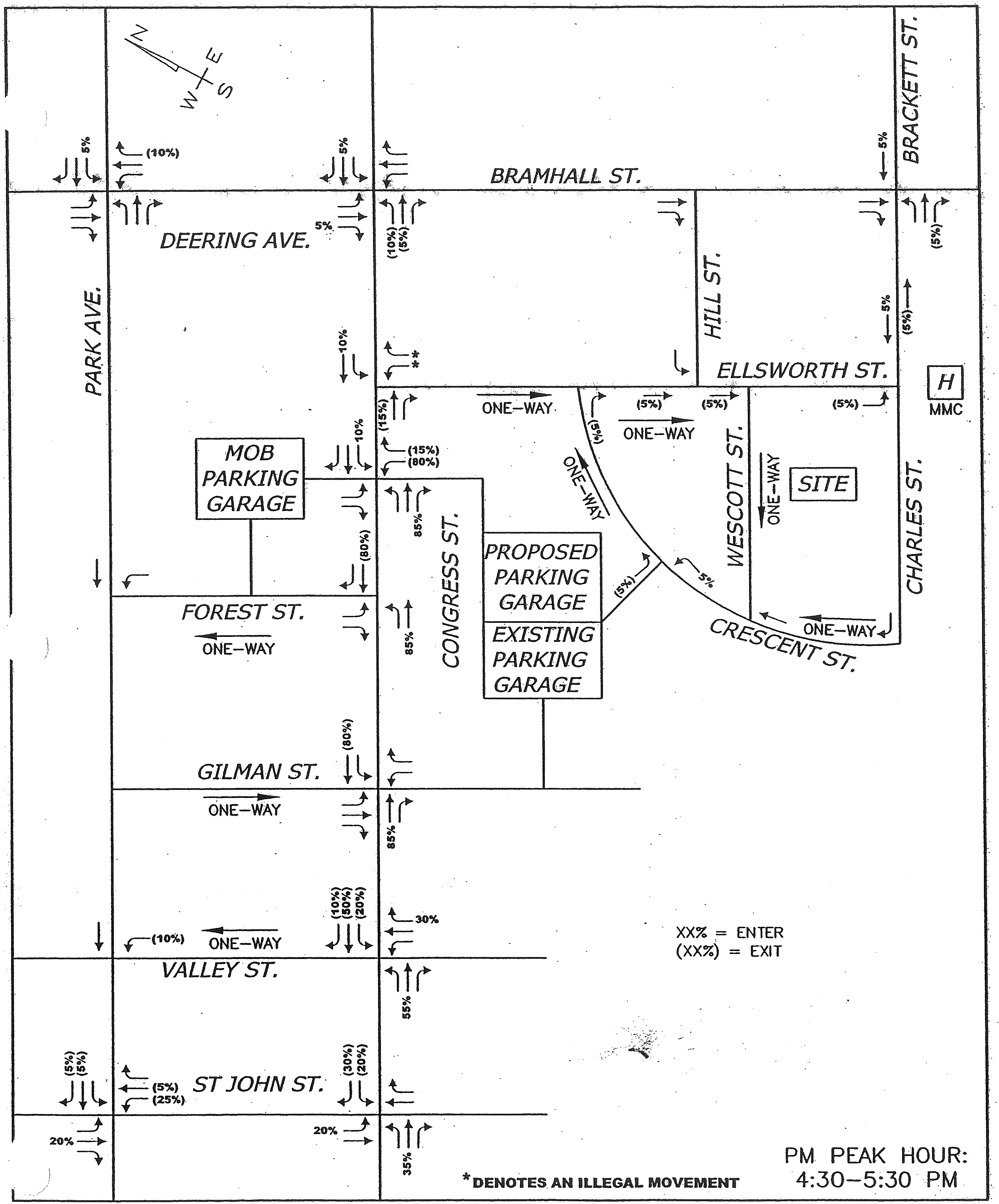
Drawing Name:
Primary Trip Distribution

Project:
MAINE MEDICAL CENTER

Figure No.
6



XX% = ENTER
(XX%) = EXIT

*DENOTES AN ILLEGAL MOVEMENT

PM PEAK HOUR:
4:30–5:30 PM

Design: MJM	Date: JAN 04
Draft: DB	Job No.: 317
Checked: RCN	Scale: NONE
File Name: 317-TRAF2.DWG	

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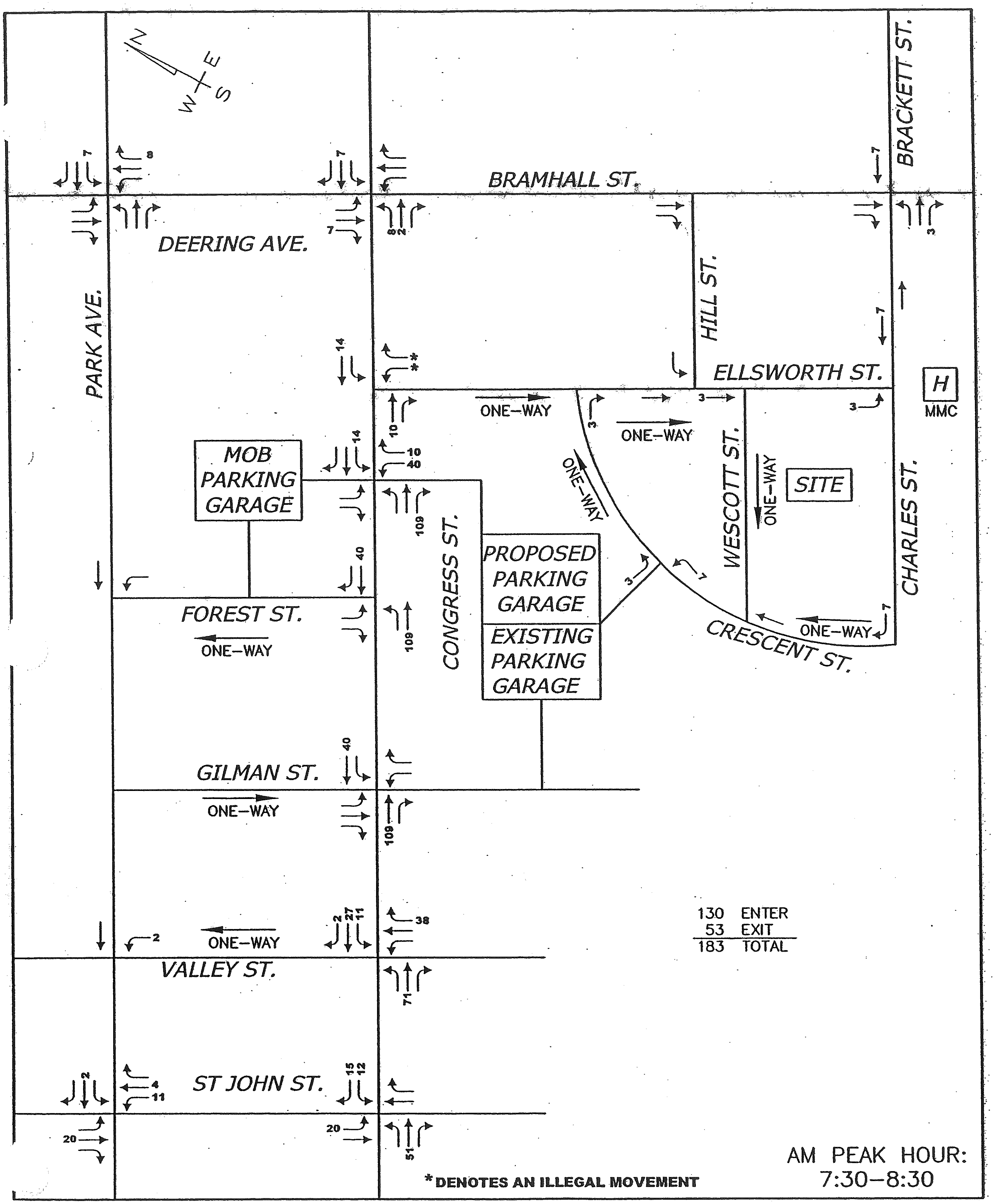
Drawing Name:
Primary Trip Distribution

Project:
MAINE MEDICAL CENTER

Figure No.
7



130	ENTER
53	EXIT
183	TOTAL

AM PEAK HOUR:
7:30–8:30

*** DENOTES AN ILLEGAL MOVEMENT**

Design: MJM	Date: JAN 04
Draft: DB	Job No.: 317
Checked: RCN	Scale: NONE
File Name: 317-TRAF2.DWG	

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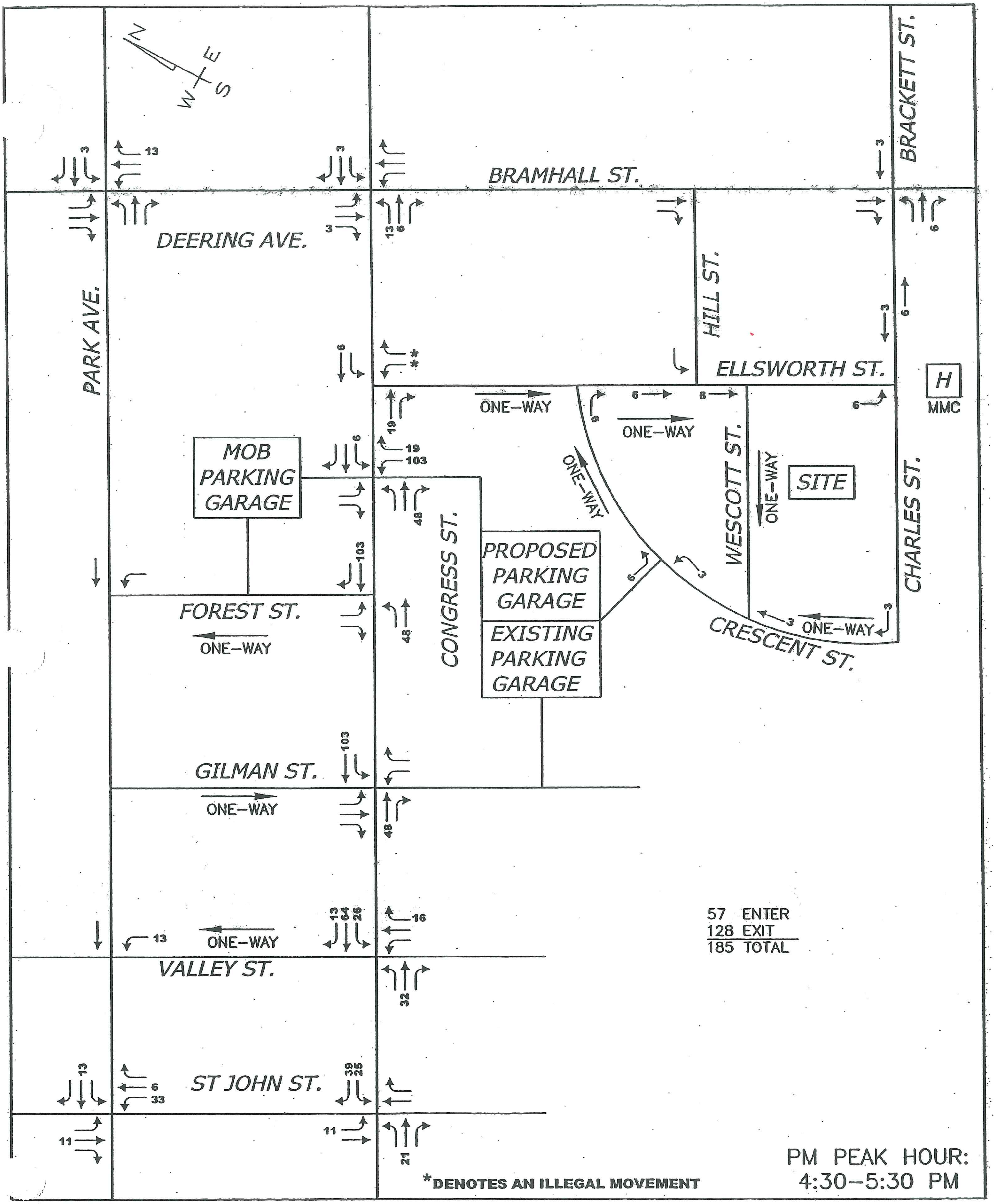
Drawing Name:
Primary Trip Assignment

Project:
MAINE MEDICAL CENTER

Figure No.
8



Design: MJM
Date: JAN 04
Draft: DB
Job No.: 317
Checked: RCN
Scale: NONE
File Name: 317–TRAF2.DWG

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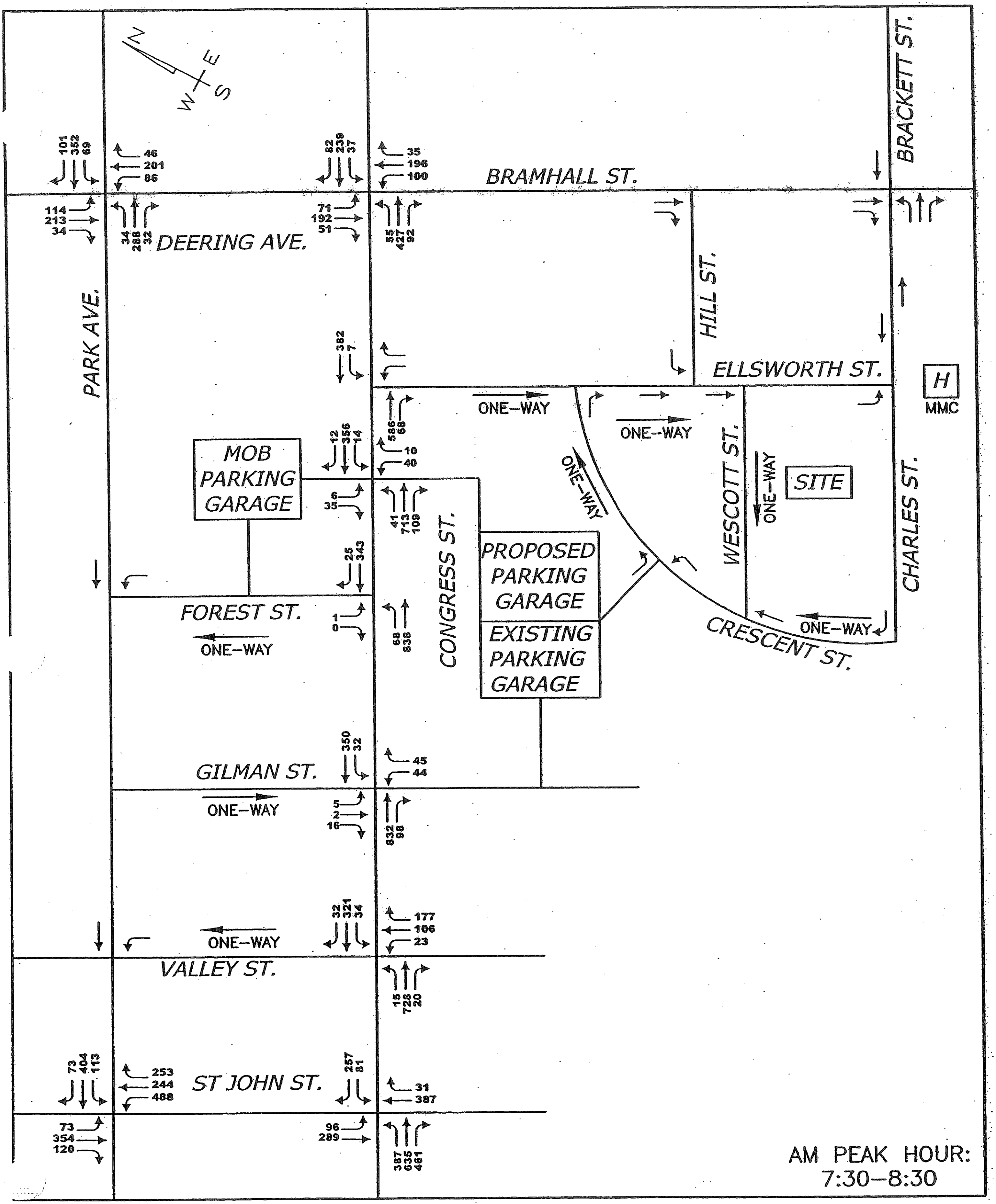
Drawing Name:
Primary Trip Assignment

Project:
MAINE MEDICAL CENTER

Figure No.
9



AM PEAK HOUR:
7:30–8:30

Design: MJM	Date: JAN 04
Draft: DB	Job No.: 317
Checked: RCN	Scale: NONE
File Name: 317-TRAF2.DWG	

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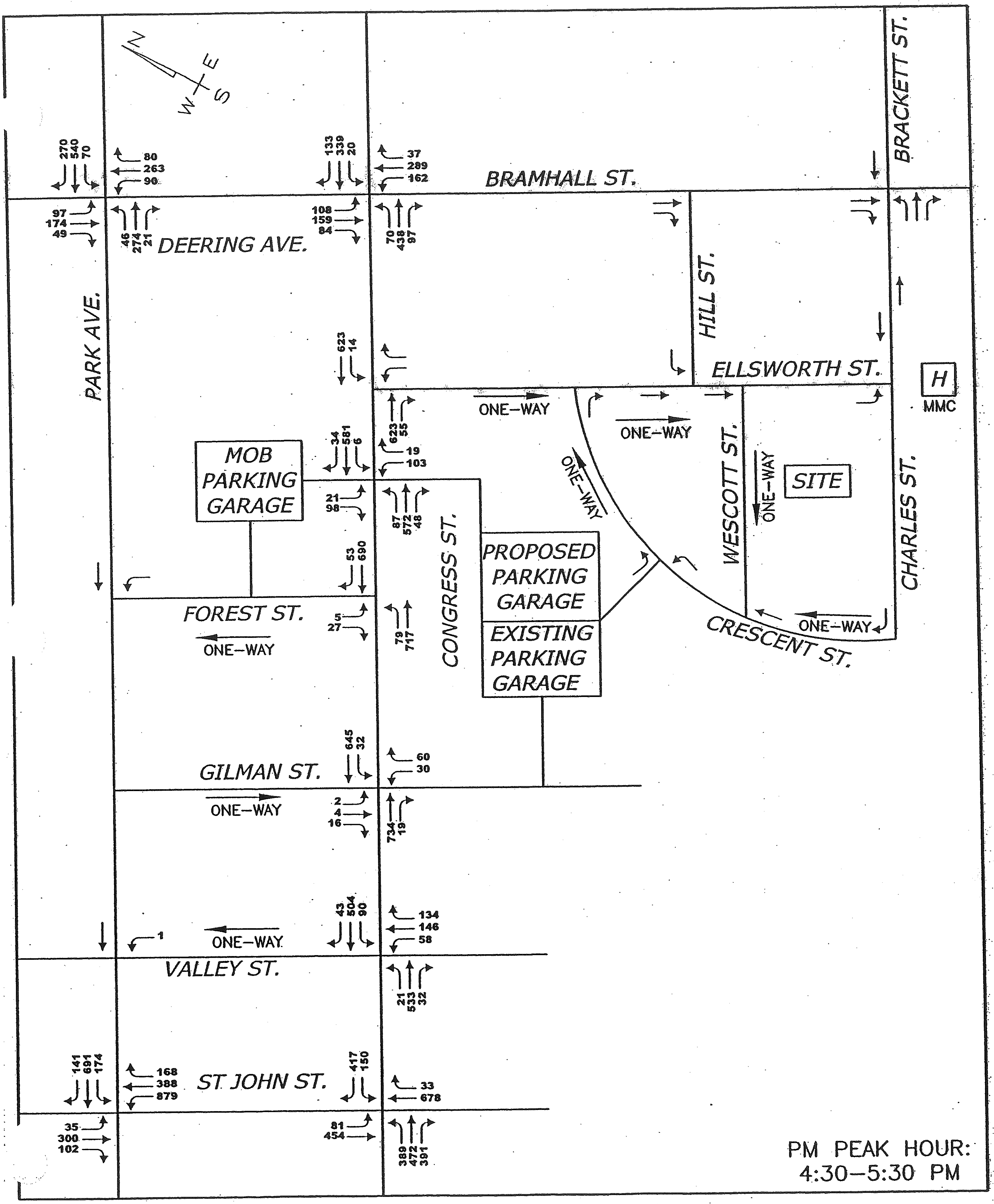
Drawing Name:
2007 Postdevelopment Volumes
Project:
MAINE MEDICAL CENTER

Figure No.
10



PM PEAK HOUR:
4:30–5:30 PM

Design: MJM	Date: JAN 04
Draft: DB	Job No.: 317
Checked: RCN	Scale: NONE

GP

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Traffic and Civil Engineering Services

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Phone: 207-657-6910
Fax: 207-657-6912

Drawing Name:
2007 Postdevelopment Volumes

Project:
MAINE MEDICAL CENTER

Figure No.
11

Appendix B

Capacity Analyses

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↱		↰	↱		↰	↱			↰	↱
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	1425	1550	0	1464	1547	0	1425	1564	0	0	1656	1411
Flt Permitted	0.517			0.286			0.390				0.000	
Satd. Flow (perm)	776	1550	0	441	1547	0	585	1564	0	0	0	1411
Satd. Flow (RTOR)		22			49			13				57
Volume (vph)	47	425	92	37	232	82	100	196	35	71	192	44
Peak Hour Factor	1.00	0.89	0.83	1.00	0.96	0.86	0.88	0.89	0.83	1.00	0.84	0.77
Heavy Vehicles (%)	14%	4%	21%	11%	7%	3%	14%	4%	21%	2%	2%	3%
Lane Group Flow (vph)	47	589	0	37	337	0	114	262	0	0	300	57
Turn Type	Perm			pm+pt			Perm			Perm		Perm
Protected Phases		4		3	8			6			2	
Permitted Phases	4			8			6			2	6	2
Total Split (s)	41.0	41.0	0.0	9.0	50.0	0.0	25.0	25.0	0.0	25.0	25.0	25.0
Act Effct Green (s)	26.3	26.3		33.1	30.5		16.7	16.7			16.7	16.7
Actuated g/C Ratio	0.46	0.46		0.55	0.54		0.29	0.29			0.29	0.29
v/c Ratio	0.13	0.81		0.11	0.39		0.66	0.56			0.62	0.13
Uniform Delay, d1	9.1	13.0		5.6	5.5		18.2	16.6			17.9	0.0
Delay	10.6	15.3		6.6	6.2		33.7	20.1			21.3	6.7
LOS	B	B		A	A		C	C			C	A
Approach Delay		15.0			6.2			24.2			19.0	
Approach LOS		B			A			C			B	
Queue Length 50th (ft)	11	202		6	57		43	90			111	0
Queue Length 95th (ft)	29	330		16	101		#124	171			186	18
Internal Link Dist (ft)		756			1600			1360			1184	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)	75			75								
50th Bay Block Time %		37%										
95th Bay Block Time %		41%			15%							
Queuing Penalty (veh)		18			3							

Intersection Summary

Cycle Length: 75

Actuated Cycle Length: 56.7

Control Type: Actuated-Uncoordinated

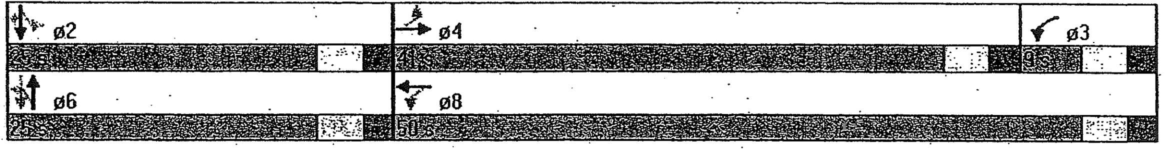
Maximum v/c Ratio: 0.81

Intersection Signal Delay: 15.9 Intersection LOS: B

Intersection Capacity Utilization 78.9% ICU Level of Service C

\# 95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 16: Congress Street & Deering Avenue



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Configurations		↰↑↱			↰	↱	↰	↱				
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	0	3400	0	0	1778	1553	1805	1653	0	0	0	0
Flt Permitted		0.930			0.906		0.950					
Satd. Flow (perm)	0	3171	0	0	1618	1553	1805	1653	0	0	0	0
Satd. Flow (RTOR)		6				15		91				
Volume (vph)	15	657	20	23	294	30	23	106	139	0	0	0
Peak Hour Factor	0.41	0.98	0.90	0.75	0.86	1.00	0.63	0.90	0.79	0.92	0.92	0.92
Heavy Vehicles (%)	8%	5%	11%	0%	7%	4%	0%	4%	5%	2%	2%	2%
Lane Group Flow (vph)	0	729	0	0	373	30	37	294	0	0	0	0
Turn Type	pm+pt			Perm		Perm	Perm					
Protected Phases	7	4			8			2				
Permitted Phases	4			8		8	2					
Total Split (s)	20.0	55.0	0.0	35.0	35.0	35.0	35.0	35.0	0.0	0.0	0.0	0.0
Act Effct Green (s)		25.5			25.5	25.5	56.4	56.4				
Actuated g/C Ratio		0.28			0.28	0.28	0.63	0.63				
v/c Ratio		0.81			0.81	0.07	0.03	0.27				
Uniform Delay, d1		29.7			30.0	11.7	6.4	4.9				
Delay		29.1			29.4	13.3	8.0	6.0				
LOS		C			C	B	A	A				
Approach Delay		29.1			28.2			6.3				
Approach LOS		C			C			A				
Queue Length 50th (ft)		198			195	6	7	45				
Queue Length 95th (ft)		241			259	24	15	100				
Internal Link Dist (ft)		776			1008			870			1150	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)						50	125					
50th Bay Block Time %					55%							
95th Bay Block Time %					53%							
Queuing Penalty (veh)					16							

Intersection Summary

Cycle Length: 90

Actuated Cycle Length: 90

Offset: 0 (0%), Referenced to phase 2:NBTL and 6:, Start of Green

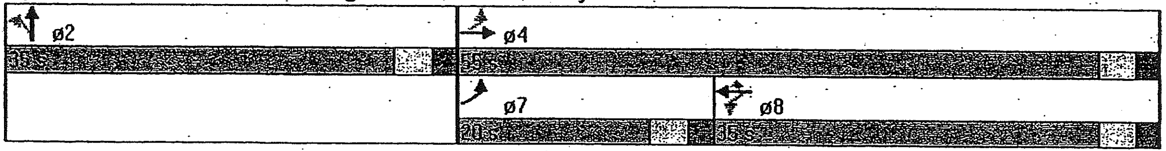
Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.81

Intersection Signal Delay: 23.7 Intersection LOS: C

Intersection Capacity Utilization 60.5% ICU Level of Service B

Splits and Phases: 9: Congress Street & Valley Street



5: Congress Street & St. John Street

4/5/2004

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↑↱		↰		↱		↑↑↱			↰↑↑	
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	1703	3214	0	1492	0	1583	0	3332	0	0	3447	0
Flt Permitted	0.950			0.950							0.591	
Satd. Flow (perm)	1703	3214	0	1492	0	1583	0	3332	0	0	2066	0
Satd. Flow (RTOR)		329				210		11				
Volume (vph)	387	584	461	69	0	242	0	387	31	76	289	0
Peak Hour Factor	0.84	0.90	0.87	1.00	0.92	0.93	0.92	0.88	0.73	0.70	1.00	0.92
Heavy Vehicles (%)	6%	3%	7%	21%	2%	2%	2%	3%	48%	4%	3%	2%
Lane Group Flow (vph)	461	1179	0	69	0	260	0	482	0	0	398	0
Turn Type	Prot			Prot		custom				custom		
Protected Phases	3	8		7		4		2		1	6	
Permitted Phases						4				1		
Total Split (s)	29.0	39.0	0.0	11.0	0.0	21.0	0.0	21.0	0.0	9.0	30.0	0.0
Act Effct Green (s)	24.1	31.9		7.0		12.6		22.4			31.4	
Actuated g/C Ratio	0.30	0.40		0.09		0.16		0.28			0.39	
v/c Ratio	0.90	0.80		0.53		0.61		0.51			0.44	
Uniform Delay, d1	26.8	14.8		36.0		5.5		24.4			17.5	
Delay	36.3	14.9		38.9		7.5		25.5			18.7	
LOS	D	B		D		A		C			B	
Approach Delay		20.9			14.1			25.5			18.7	
Approach LOS		C			B			C			B	
Queue Length 50th (ft)	215	201		34		22		106			72	
Queue Length 95th (ft)	#338	258		#84		85		161			116	
Internal Link Dist (ft)		1004			776			849			1196	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)												
50th Bay Block Time %												
95th Bay Block Time %												
Queuing Penalty (veh)												

Intersection Summary

Cycle Length: 80

Actuated Cycle Length: 80

Offset: 6 (8%), Referenced to phase 2:NBT and 6:SBT, Start of Green

Control Type: Actuated-Coordinated

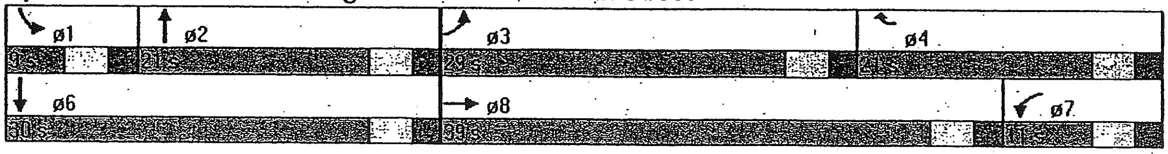
Maximum v/c Ratio: 0.90

Intersection Signal Delay: 20.6 Intersection LOS: C

Intersection Capacity Utilization 76.7% ICU Level of Service C

\# 95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 5: Congress Street & St. John Street



6: Park Avenue & St. John Street

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations					↰↑	↱	↰	↰	↱		↰	↱
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	0	0	0	0	3381	1599	1649	1723	1524	0	1840	1538
Flt Permitted					0.991		0.950	0.981			0.990	
Satd. Flow (perm)	0	0	0	0	3381	1599	1649	1723	1524	0	1840	1538
Satd. Flow (RTOR)						73			257			118
Volume (vph)	0	0	0	113	402	73	477	240	253	73	334	120
Peak Hour Factor	0.92	0.92	0.92	1.00	0.78	1.00	0.91	1.00	0.86	0.76	0.93	0.87
Heavy Vehicles (%)	2%	2%	2%	5%	6%	1%	4%	2%	6%	3%	2%	5%
Lane Group Flow (vph)	0	0	0	0	628	73	368	396	294	0	455	138
Turn Type				Prot		Perm	Split		Perm	Split		Perm
Protected Phases				3	8		6	6		2	2	
Permitted Phases						8			6			2
Total Split (s)	0.0	0.0	0.0	24.0	24.0	24.0	32.0	32.0	32.0	24.0	24.0	24.0
Act Effct Green (s)					20.1	20.1	23.2	23.2	23.2		20.1	20.1
Actuated g/C Ratio					0.27	0.27	0.31	0.31	0.31		0.27	0.27
v/c Ratio					0.70	0.15	0.73	0.75	0.46		0.93	0.28
Uniform Delay, d1					24.9	0.0	23.2	23.4	2.3		26.9	3.0
Delay					26.3	6.6	23.3	23.5	4.2		56.2	7.1
LOS					C	A	C	C	A		E	A
Approach Delay					24.2			18.1			44.8	
Approach LOS					C			B			D	
Queue Length 50th (ft)					146	0	158	172	12		218	7
Queue Length 95th (ft)					176	30	256	274	56		#413	47
Internal Link Dist (ft)		1008			4892			1196			806	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)						200			100			
50th Bay Block Time %								31%				
95th Bay Block Time %								43%				
Queuing Penalty (veh)								108				

Intersection Summary

Cycle Length: 80

Actuated Cycle Length: 75.5

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.93

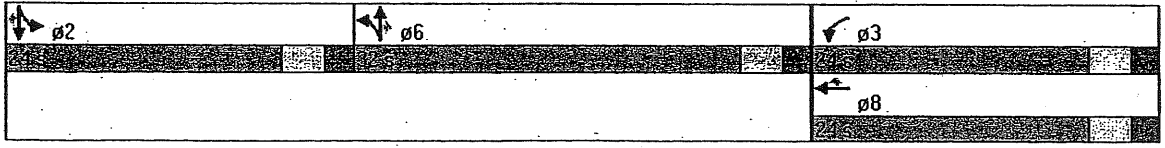
Intersection Signal Delay: 26.6 Intersection LOS: C

Intersection Capacity Utilization 72.6% ICU Level of Service C

\# 95th percentile volume exceeds capacity, queue may be longer.

Queue shown is maximum after two cycles.

Splits and Phases: 6: Park Avenue & St. John Street



	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↱			↰↑	↱	↰	↑↱		↰	↑↱	
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	0	3049	0	0	3146	1384	1624	1655	0	1608	1641	0
Flt Permitted		0.884			0.833		0.595			0.233		
Satd. Flow (perm)	0	2706	0	0	2639	1384	1017	1655	0	394	1641	0
Satd. Flow (RTOR)		14				105		9			11	
Volume (vph)	34	288	32	62	352	101	86	200	38	114	213	34
Peak Hour Factor	1.00	0.91	1.00	0.86	0.86	0.96	1.00	0.81	1.00	0.88	0.95	0.80
Heavy Vehicles (%)	7%	4%	10%	0%	3%	5%	0%	1%	3%	1%	2%	0%
Lane Group Flow (vph)	0	382	0	0	481	105	86	285	0	130	266	0
Turn Type	Perm			Perm		Perm	pm+pt			pm+pt		
Protected Phases		4			8		1	6		5	2	
Permitted Phases	4			8		8	6			2		
Total Split (s)	45.0	45.0	0.0	45.0	45.0	45.0	10.0	30.0	0.0	15.0	35.0	0.0
Act Effct Green (s)		16.4			16.4	16.4	16.8	15.2		17.4	17.7	
Actuated g/C Ratio		0.32			0.32	0.32	0.30	0.30		0.33	0.35	
v/c Ratio		0.43			0.57	0.20	0.21	0.57		0.38	0.46	
Uniform Delay, d1		13.7			15.0	0.0	13.3	14.2		12.4	12.9	
Delay		15.0			16.3	4.2	17.7	17.3		16.4	16.4	
LOS		B			B	A	B	B		B	B	
Approach Delay		15.0			14.2			17.4			16.4	
Approach LOS		B			B			B			B	
Queue Length 50th (ft)		47			65	0	20	72		31	67	
Queue Length 95th (ft)		101			126	30	59	149		83	163	
Internal Link Dist (ft)		4892			1568			1184			904	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)						150	125			75		
50th Bay Block Time %											4%	
95th Bay Block Time %								17%		14%	41%	
Queuing Penalty (veh)								7		18	26	

Intersection Summary

Cycle Length: 90

Actuated Cycle Length: 51.1

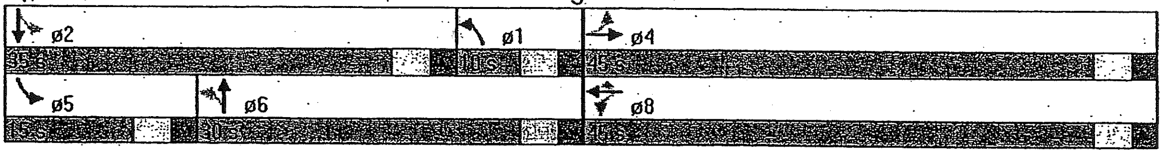
Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.57

Intersection Signal Delay: 15.6 Intersection LOS: B

Intersection Capacity Utilization 65.2% ICU Level of Service B

Splits and Phases: 17: Park Avenue & Deering Avenue



HCM Unsignalized Intersection Capacity Analysis
12: Congress Street & Forest Street

	↗	→	←	↖	↘	↙
Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations		↰	↱		Y	
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Volume (veh/h)	68	729	337	25	1	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00
Hourly flow rate (veh/h)	68	729	337	25	1	0
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type					None	
Median storage veh)						
Upstream signal (ft)						
pX, platoon unblocked						
vC, conflicting volume	362				1214	350
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	362				1214	350
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	94				99	100
cM capacity (veh/h)	1208				191	698

Direction, Lane #	EB 1	WB 1	SB 1
Volume Total	797	362	1
Volume Left	68	0	1
Volume Right	0	25	0
cSH	1208	1700	191
Volume to Capacity	0.06	0.21	0.01
Queue Length (ft)	4	0	0
Control Delay (s)	1.4	0.0	24.0
Lane LOS	A		C
Approach Delay (s)	1.4	0.0	24.0
Approach LOS			C

Intersection Summary			
Average Delay	1.0		
Intersection Capacity Utilization	74.7%	ICU Level of Service	C

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↱			↰		↰		↱		✥	
Sign Control		Free			Free			Stop			Stop	
Grade		0%			0%			0%			0%	
Volume (veh/h)	0	723	98	32	310	0	44	0	45	5	2	16
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Hourly flow rate (veh/h)	0	723	98	32	310	0	44	0	45	5	2	16
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)		1088										
pX, platoon unblocked				0.72			0.72	0.72	0.72	0.72	0.72	
vC, conflicting volume	310			821			1163	1146	772	1191	1195	310
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	310			751			1227	1203	682	1266	1272	310
tC, single (s)	4.1			4.1			7.1	6.5	6.2	7.1	6.5	6.2
tC, 2 stage (s)												
tF (s)	2.2			2.2			3.5	4.0	3.3	3.5	4.0	3.3
p0 queue free %	100			95			58	100	86	94	98	98
cM capacity (veh/h)	1262			620			104	127	324	87	115	735

Direction, Lane #	EB 1	WB 1	NB 1	NB 2	SB 1
Volume Total	821	342	44	45	23
Volume Left	0	32	44	0	5
Volume Right	98	0	0	45	16
cSH	1700	620	104	324	239
Volume to Capacity	0.48	0.05	0.42	0.14	0.10
Queue Length (ft)	0	4	45	12	8
Control Delay (s)	0.0	1.7	63.1	17.9	21.7
Lane LOS		A	F	C	C
Approach Delay (s)	0.0	1.7	40.2		21.7
Approach LOS			E		C

Intersection Summary			
Average Delay	3.7		
Intersection Capacity Utilization	60.7%	ICU Level of Service	B

HCM Unsignalized Intersection Capacity Analysis T:\317\Synchro\2007\2007 Pre AM.sy6
30: Congress Street & EXISTING DRIVE 4/2/2004

	↗	→	←	↖	↘	↙
Movement	**EBL**	**EBT**	**WBT**	**WBR**	**SBL**	**SBR**
Lane Configurations	↰	↑	↱		Y	
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Volume (veh/h)	41	713	356	12	6	36
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00
Hourly flow rate (veh/h)	41	713	356	12	6	36
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type					None	
Median storage veh)						
Upstream signal (ft)						
pX, platoon unblocked						
vC, conflicting volume	368				1157	362
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	368				1157	362
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	97				97	95
cM capacity (veh/h)	1174				207	676

Direction, Lane #	EB 1	EB 2	WB 1	SB 1
Volume Total	41	713	368	42
Volume Left	41	0	0	6
Volume Right	0	0	12	36
cSH	1174	1700	1700	510
Volume to Capacity	0.03	0.42	0.22	0.08
Queue Length (ft)	3	0	0	7
Control Delay (s)	8.2	0.0	0.0	12.7
Lane LOS	A			B
Approach Delay (s)	0.4		0.0	12.7
Approach LOS				B

Intersection Summary			
Average Delay	0.7		
Intersection Capacity Utilization	47.5%	ICU Level of Service	A

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↱		↰	↱		↰	↱			↰	↱
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	1425	1551	0	1464	1549	0	1425	1564	0	0	1656	1411
Flt Permitted	0.512			0.284			0.390				0.000	
Satd. Flow (perm)	768	1551	0	438	1549	0	585	1564	0	0	0	1411
Satd. Flow (RTOR)		22			47			13				66
Volume (vph)	55	427	92	37	239	82	100	196	35	71	192	51
Peak Hour Factor	1.00	0.89	0.83	1.00	0.96	0.86	0.88	0.89	0.83	1.00	0.84	0.77
Heavy Vehicles (%)	14%	4%	21%	11%	7%	3%	14%	4%	21%	2%	2%	3%
Lane Group Flow (vph)	55	591	0	37	344	0	114	262	0	0	300	66
Turn Type	Perm			pm+pt			Perm			Perm		Perm
Protected Phases		4		3	8			6			2	
Permitted Phases	4			8			6			2	6	2
Total Split (s)	41.0	41.0	0.0	9.0	50.0	0.0	25.0	25.0	0.0	25.0	25.0	25.0
Act Effct Green (s)	26.3	26.3		33.1	30.5		16.6	16.6			16.6	16.6
Actuated g/C Ratio	0.46	0.46		0.55	0.54		0.29	0.29			0.29	0.29
v/c Ratio	0.15	0.81		0.11	0.40		0.66	0.56			0.62	0.14
Uniform Delay, d1	9.2	13.1		5.6	5.6		18.2	16.6			17.9	0.0
Delay	10.7	15.5		6.6	6.2		33.7	20.1			21.3	6.4
LOS	B	B		A	A		C	C			C	A
Approach Delay		15.1			6.3			24.2			18.6	
Approach LOS		B			A			C			B	
Queue Length 50th (ft)	13	203		6	59		43	90			111	0
Queue Length 95th (ft)	33	331		16	104		#124	171			186	19
Internal Link Dist (ft)		756			1600			1360			1184	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)	75			75								
50th Bay Block Time %		37%			1%							
95th Bay Block Time %		41%			16%							
Queuing Penalty (veh)		21			3							

Intersection Summary

Cycle Length: 75

Actuated Cycle Length: 56.7

Control Type: Actuated-Uncoordinated

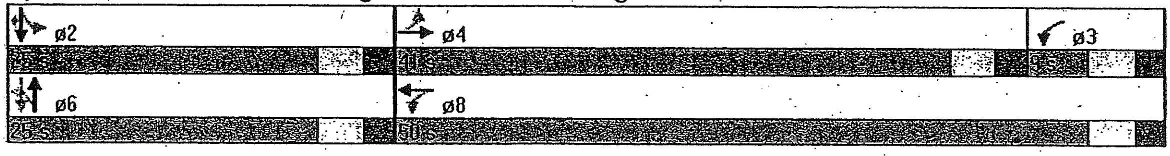
Maximum v/c Ratio: 0.81

Intersection Signal Delay: 15.9 Intersection LOS: B

Intersection Capacity Utilization 79.0% ICU Level of Service C

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 16: Congress Street & Deering Avenue

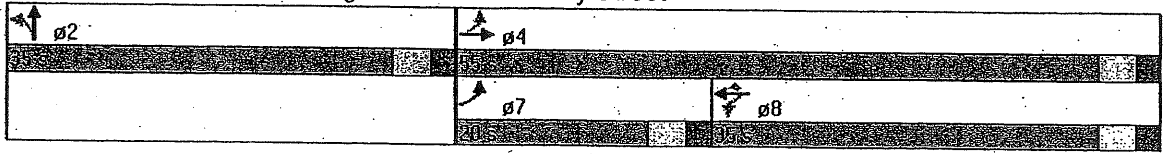


	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↱			↰↑	↱	↰	↑↱				
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	0	3408	0	0	1779	1553	1805	1638	0	0	0	0
Flt Permitted		0.928			0.856		0.950					
Satd. Flow (perm)	0	3169	0	0	1531	1553	1805	1638	0	0	0	0
Satd. Flow (RTOR)		5				14		116				
Volume (vph)	15	728	20	34	321	32	23	106	177	0	0	0
Peak Hour Factor	0.41	0.98	0.90	0.75	0.86	1.00	0.63	0.90	0.79	0.92	0.92	0.92
Heavy Vehicles (%)	8%	5%	11%	0%	7%	4%	0%	4%	5%	2%	2%	2%
Lane Group Flow (vph)	0	802	0	0	418	32	37	342	0	0	0	0
Turn Type	pm+pt			Perm		Perm	Perm					
Protected Phases	7	4			8			2				
Permitted Phases	4			8		8	2					
Total Split (s)	20.0	55.0	0.0	35.0	35.0	35.0	35.0	35.0	0.0	0.0	0.0	0.0
Act Effct Green (s)		28.9			28.9	28.9	53.1	53.1				
Actuated g/C Ratio		0.32			0.32	0.32	0.59	0.59				
v/c Ratio		0.78			0.85	0.06	0.03	0.34				
Uniform Delay, d1		27.5			28.5	11.8	7.7	5.9				
Delay		27.0			28.1	12.7	9.4	7.0				
LOS		C			C	B	A	A				
Approach Delay		27.0			27.0			7.2				
Approach LOS		C			C			A				
Queue Length 50th (ft)		206			212	7	9	60				
Queue Length 95th (ft)		255			286	24	17	126				
Internal Link Dist (ft)		776			1008			870			1150	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)						50	125					
50th Bay Block Time %					52%							
95th Bay Block Time %					52%			7%				
Queuing Penalty (veh)					16			1				

Intersection Summary

Cycle Length: 90
Actuated Cycle Length: 90
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:, Start of Green
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.85
Intersection Signal Delay: 22.4 Intersection LOS: C
Intersection Capacity Utilization 74.4% ICU Level of Service C

Splits and Phases: 9: Congress Street & Valley Street



	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↱		↰		↱		↑↱			↰↑	
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	1703	3227	0	1492	0	1583	0	3332	0	0	3438	0
Flt Permitted	0.950			0.950							0.560	
Satd. Flow (perm)	1703	3227	0	1492	0	1583	0	3332	0	0	1957	0
Satd. Flow (RTOR)		301				210		11				
Volume (vph)	387	636	461	81	0	257	0	387	31	96	289	0
Peak Hour Factor	0.84	0.90	0.87	1.00	0.92	0.93	0.92	0.88	0.73	0.70	1.00	0.92
Heavy Vehicles (%)	6%	3%	7%	21%	2%	2%	2%	3%	48%	4%	3%	2%
Lane Group Flow (vph)	461	1237	0	81	0	276	0	482	0	0	426	0
Turn Type	Prot			Prot		custom				custom		
Protected Phases	3	8		7		4		2		1	6	
Permitted Phases						4				1		
Total Split (s)	29.0	39.0	0.0	11.0	0.0	21.0	0.0	21.0	0.0	9.0	30.0	0.0
Act Effct Green (s)	24.1	32.8		7.0		13.5		21.5			30.5	
Actuated g/C Ratio	0.30	0.41		0.09		0.17		0.27			0.38	
v/c Ratio	0.90	0.83		0.62		0.63		0.53			0.51	
Uniform Delay, d1	26.8	15.5		36.4		6.8		25.2			18.4	
Delay	36.3	15.7		44.9		8.4		26.2			19.6	
LOS	D	B		D		A		C			B	
Approach Delay		21.3			16.7			26.2			19.6	
Approach LOS		C			B			C			B	
Queue Length 50th (ft)	215	215		40		28		111			82	
Queue Length 95th (ft)	#338	291		#102		97		161			124	
Internal Link Dist (ft)		1004			776			849			1196	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)												
50th Bay Block Time %												
95th Bay Block Time %												
Queuing Penalty (veh)												

Intersection Summary

Cycle Length: 80

Actuated Cycle Length: 80

Offset: 0 (0%), Referenced to phase 2:NBT and 6:SBT, Start of Green

Control Type: Actuated-Coordinated

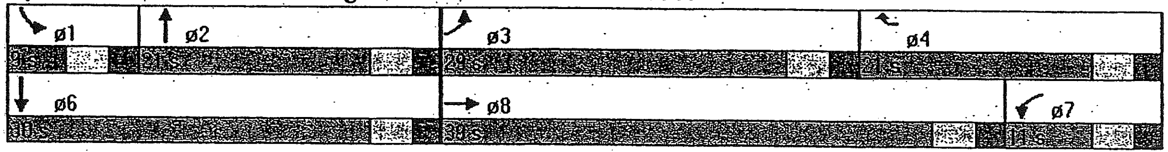
Maximum v/c Ratio: 0.90

Intersection Signal Delay: 21.3 Intersection LOS: C

Intersection Capacity Utilization 79.8% ICU Level of Service C

\# 95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 5: Congress Street & St. John Street



	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations					↰↑	↱	↰	↰	↱		↰	↱
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	0	0	0	0	3381	1599	1649	1723	1524	0	1840	1538
Flt Permitted					0.991		0.950	0.981			0.990	
Satd. Flow (perm)	0	0	0	0	3381	1599	1649	1723	1524	0	1840	1538
Satd. Flow (RTOR)						73			252			114
Volume (vph)	0	0	0	113	404	73	488	244	253	73	354	120
Peak Hour Factor	0.92	0.92	0.92	1.00	0.78	1.00	0.91	1.00	0.86	0.76	0.93	0.87
Heavy Vehicles (%)	2%	2%	2%	5%	6%	1%	4%	2%	6%	3%	2%	5%
Lane Group Flow (vph)	0	0	0	0	631	73	376	404	294	0	477	138
Turn Type				Prot		Perm	Split		Perm	Split		Perm
Protected Phases				3	8		6	6		2	2	
Permitted Phases						8			6			2
Total Split (s)	0.0	0.0	0.0	24.0	24.0	24.0	32.0	32.0	32.0	24.0	24.0	24.0
Act Effct Green (s)					20.1	20.1	23.4	23.4	23.4		20.1	20.1
Actuated g/C Ratio					0.27	0.27	0.31	0.31	0.31		0.27	0.27
v/c Ratio					0.70	0.15	0.74	0.76	0.46		0.98	0.28
Uniform Delay, d1					25.0	0.0	23.3	23.5	2.7		27.5	3.6
Delay					26.5	6.6	23.5	23.6	4.4		61.8	7.6
LOS					C	A	C	C	A		E	A
Approach Delay					24.4			18.3			49.6	
Approach LOS					C			B			D	
Queue Length 50th (ft)					148	0	164	177	14		~239	9
Queue Length 95th (ft)					176	30	263	281	58		#439	48
Internal Link Dist (ft)		1008			4892			1196			806	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)						200			100			
50th Bay Block Time %								32%				
95th Bay Block Time %								43%				
Queuing Penalty (veh)								110				

Intersection Summary

Cycle Length: 80

Actuated Cycle Length: 75.7

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.98

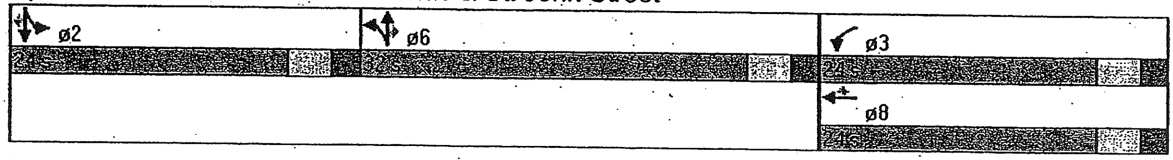
Intersection Signal Delay: 28.2 Intersection LOS: C

Intersection Capacity Utilization 74.2% ICU Level of Service C

~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.

\# 95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 6: Park Avenue & St. John Street

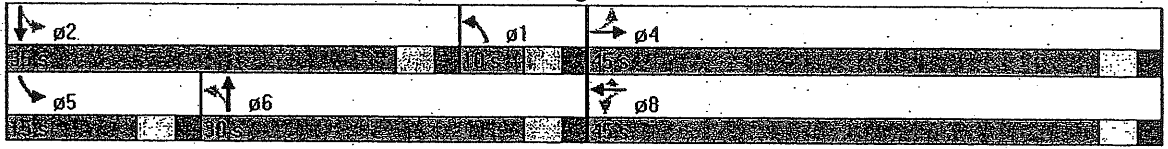


Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↱			↰↑	↱	↰	↑↱		↰	↑↱	
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	0	3049	0	0	3144	1384	1624	1649	0	1608	1641	0
Flt Permitted		0.883			0.820		0.595			0.218		
Satd. Flow (perm)	0	2703	0	0	2599	1384	1017	1649	0	369	1641	0
Satd. Flow (RTOR)		14				105		10			11	
Volume (vph)	34	288	32	69	352	101	86	201	46	114	213	34
Peak Hour Factor	1.00	0.91	1.00	0.86	0.86	0.96	1.00	0.81	1.00	0.88	0.95	0.80
Heavy Vehicles (%)	7%	4%	10%	0%	3%	5%	0%	1%	3%	1%	2%	0%
Lane Group Flow (vph)	0	382	0	0	489	105	86	294	0	130	266	0
Turn Type	Perm			Perm		Perm	pm+pt			pm+pt		
Protected Phases		4			8		1	6		5	2	
Permitted Phases	4			8		8	6			2		
Total Split (s)	45.0	45.0	0.0	45.0	45.0	45.0	10.0	30.0	0.0	15.0	35.0	0.0
Act Effct Green (s)		16.8			16.8	16.8	17.3	15.7		17.6	17.9	
Actuated g/C Ratio		0.32			0.32	0.32	0.31	0.30		0.33	0.34	
v/c Ratio		0.43			0.58	0.20	0.21	0.58		0.38	0.46	
Uniform Delay, d1		13.8			15.2	0.0	13.5	14.4		12.6	13.2	
Delay		15.2			16.6	4.2	17.8	17.5		16.9	16.9	
LOS		B			B	A	B	B		B	B	
Approach Delay		15.2			14.4			17.6			16.9	
Approach LOS		B			B			B			B	
Queue Length 50th (ft)		48			68	0	20	76		32	69	
Queue Length 95th (ft)		103			131	30	59	155		85	168	
Internal Link Dist (ft)		4892			1568			1184			904	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)						150	125			75		
50th Bay Block Time %											6%	
95th Bay Block Time %								19%		15%	42%	
Queuing Penalty (veh)								8		20	27	

Intersection Summary

Cycle Length: 90
Actuated Cycle Length: 52
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 0.58
Intersection Signal Delay: 15.8 Intersection LOS: B
Intersection Capacity Utilization 66.0% ICU Level of Service B

Splits and Phases: 17: Park Avenue & Deering Avenue



12: Congress Street & Forest Street

	↗	→	←	↖	↘	↙
Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations		↰	↱		Y	
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Volume (veh/h)	68	838	377	25	1	0
Peak Hour Factor	0.67	0.96	0.86	1.00	1.00	1.00
Hourly flow rate (veh/h)	101	873	438	25	1	0
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type					None	
Median storage veh)						
Upstream signal (ft)						
pX, platoon unblocked						
vC, conflicting volume	463				1527	451
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	463				1527	451
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	91				99	100
cM capacity (veh/h)	1108				119	613

Direction, Lane #	EB 1	WB 1	SB 1
Volume Total	974	463	1
Volume Left	101	0	1
Volume Right	0	25	0
cSH	1108	1700	119
Volume to Capacity	0.09	0.27	0.01
Queue Length (ft)	8	0	1
Control Delay (s)	2.3	0.0	35.6
Lane LOS	A		E
Approach Delay (s)	2.3	0.0	35.6
Approach LOS			E

Intersection Summary			
Average Delay	1.6		
Intersection Capacity Utilization	89.5%	ICU Level of Service	D

HCM Unsignalized Intersection Capacity Analysis T:\817\Synchro\2007\2007 Post AMrev3-2-04.sy6
27: Congress Street & Gilman Street
4/2/2004

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↱			↰		↰		↱		✣	
Sign Control		Free			Free			Stop			Stop	
Grade		0%			0%			0%			0%	
Volume (veh/h)	0	832	98	32	350	0	44	0	45	5	2	16
Peak Hour Factor	0.90	0.97	0.90	0.90	0.86	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Hourly flow rate (veh/h)	0	858	109	36	407	0	49	0	50	6	2	18
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)		1088										
pX, platoon unblocked				0.68			0.68	0.68	0.68	0.68	0.68	
vC, conflicting volume	407			967			1409	1390	912	1440	1445	407
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	407			951			1600	1572	871	1645	1652	407
tC, single (s)	4.1			4.1			7.1	6.5	6.2	7.1	6.5	6.2
tC, 2 stage (s)												
tF (s)	2.2			2.2			3.5	4.0	3.3	3.5	4.0	3.3
p0 queue free %	100			93			7	100	79	86	96	97
cM capacity (veh/h)	1163			496			53	71	240	41	63	648

Direction, Lane #	EB 1	WB 1	NB 1	NB 2	SB 1
Volume Total	967	443	49	50	26
Volume Left	0	36	49	0	6
Volume Right	109	0	0	50	18
cSH	1700	496	53	240	129
Volume to Capacity	0.57	0.07	0.93	0.21	0.20
Queue Length (ft)	0	6	102	19	18
Control Delay (s)	0.0	2.1	228.2	23.9	39.7
Lane LOS		A	F	C	E
Approach Delay (s)	0.0	2.1	124.9		39.7
Approach LOS			F		E

Intersection Summary			
Average Delay	9.3		
Intersection Capacity Utilization	68.4%	ICU Level of Service	B

30: Congress Street & EXISTING DRIVE

4/2/2004

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Movement	**EBL**	**EBT**	**EBR**	**WBL**	**WBT**	**WBR**	**NBL**	**NBT**	**NBR**	**SBL**	**SBT**	**SBR**
Lane Configurations	↰	↑↱		↰	↑↱		↰		↱		✣	
Sign Control		Free			Free			Stop			Stop	
Grade		0%			0%			0%			0%	
Volume (veh/h)	41	713	109	14	356	12	40	0	10	6	0	35
Peak Hour Factor	1.00	1.00	0.60	0.60	1.00	1.00	0.60	0.60	0.60	1.00	1.00	1.00
Hourly flow rate (veh/h)	41	713	182	23	356	12	67	0	17	6	0	35
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	368			895			1324	1300	804	1220	1385	362
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	368			895			1324	1300	804	1220	1385	362
tC, single (s)	4.1			4.1			7.2	6.6	6.2	7.2	6.6	6.2
tC, 2 stage (s)												
tF (s)	2.2			2.2			3.5	4.0	3.3	3.5	4.0	3.3
p0 queue free %	97			97			44	100	96	96	100	95
cM capacity (veh/h)	1174			746			118	149	378	140	132	676

Direction, Lane #	**EB 1**	**EB 2**	**WB 1**	**WB 2**	**NB 1**	**NB 2**	**SB 1**
Volume Total	41	895	23	368	67	17	41
Volume Left	41	0	23	0	67	0	6
Volume Right	0	182	0	12	0	17	35
cSH	1174	1700	746	1700	118	378	434
Volume to Capacity	0.03	0.53	0.03	0.22	0.56	0.04	0.09
Queue Length (ft)	3	0	2	0	68	3	8
Control Delay (s)	8.2	0.0	10.0	0.0	69.1	15.0	14.2
Lane LOS	A		A		F	B	B
Approach Delay (s)	0.4		0.6		58.3		14.2
Approach LOS					F		B

Intersection Summary			
Average Delay	4.1		
Intersection Capacity Utilization	65.6%	ICU Level of Service	B

30: Congress Street & EXISTING DRIVE Performance by movement

	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBR	SBL	SBR
Total Delay (hr)	0.0	1.0	0.3	0.0	0.1	0.0	0.2	0.0	0.0	0.0
Delay / Veh (s)	3.9	5.3	7.3	14.8	1.3	5.2	28.1	9.2	14.2	4.4
Total Stops	12	0	1	9	0	0	31	10	5	28
Travel Dist (mi)	2.9	66.9	12.0	1.0	34.7	0.9	3.8	1.2	0.7	3.7
Travel Time (hr)	0.1	3.3	0.8	0.1	1.3	0.0	0.4	0.1	0.0	0.2
Avg Speed (mph)	20	20	16	13	26	18	10	16	16	20
Fuel Used (gal)	0.2	4.3	0.8	0.2	2.1	0.1	0.3	0.1	0.0	0.2
HC Emissions (g)	1	9	2	0	4	0	1	0	0	1
CO Emissions (g)	45	180	58	6	76	5	41	8	1	21
NOx Emissions (g)	2	19	7	1	8	1	3	1	0	1
Vehicles Entered	29	687	125	10	381	9	31	10	5	28
Vehicles Exited	30	690	126	10	381	8	31	10	5	28
Hourly Exit Rate	30	690	126	10	381	8	31	10	5	28
Denied Entry Before	0	0	0	0	0	0	0	0	0	0
Denied Entry After	0	0	0	0	0	0	0	0	0	0

30: Congress Street & EXISTING DRIVE Intersection Performance

	Total
Total Delay (hr)	1.8
Delay / Veh (s)	5.0
Total Stops	96
Travel Dist (mi)	127.7
Travel Time (hr)	6.4
Avg Speed (mph)	20
Fuel Used (gal)	8.4
HC Emissions (g)	19
CO Emissions (g)	441
NOx Emissions (g)	42
Vehicles Entered	1315
Vehicles Exited	1319
Hourly Exit Rate	1319
Denied Entry Before	0
Denied Entry After	0

Intersection: 17: Park Avenue & Deering Avenue

Movement	EB	EB	WB	WB	WB	NB	NB	SB	SB
Directions Served	LT	TR	LT	T	R	L	TR	L	TR
Maximum Queue (ft)	161	163	128	113	75	148	189	100	160
Average Queue (ft)	57	66	79	67	35	43	95	55	83
95th Queue (ft)	106	119	114	106	63	94	156	98	145
Link Distance (ft)	4879	4879	1614	1614			1186		931
Upstream Blk Time (%)									
Queuing Penalty (veh)									
Storage Bay Dist (ft)					150	125		75	
Storage Blk Time (%)						0.00	0.02	0.02	0.07
Queuing Penalty (veh)						0	2	4	8

Intersection: 27: Congress Street & Gilman Street

Movement	EB	WB	NB	NB	SB
Directions Served	TR	LT	L	R	LTR
Maximum Queue (ft)	94	205	161	54	52
Average Queue (ft)	8	51	57	25	18
95th Queue (ft)	43	144	122	51	46
Link Distance (ft)	1007	1068	916	916	1192
Upstream Blk Time (%)					
Queuing Penalty (veh)					
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 30: Congress Street & EXISTING DRIVE

Movement	EB	EB	WB	NB	NB	SB
Directions Served	L	TR	L	L	R	LR
Maximum Queue (ft)	50	22	50	69	31	47
Average Queue (ft)	11	1	11	23	10	24
95th Queue (ft)	37	8	36	53	31	45
Link Distance (ft)	468	468	470	644	644	698
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)						
Storage Blk Time (%)						
Queuing Penalty (veh)						

Nework Summary

Network wide Queuing Penalty: 128

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↱		↰	↱		↰	↱			↰	↱
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	1624	1622	0	1624	1590	0	1518	1651	0	0	1644	1454
Flt Permitted	0.274			0.162			0.485				0.533	
Satd. Flow (perm)	469	1622	0	277	1590	0	775	1651	0	0	895	1454
Satd. Flow (RTOR)		16			39			15				104
Volume (vph)	57	432	97	20	336	133	162	289	37	108	159	81
Peak Hour Factor	1.00	0.93	1.00	0.75	1.00	0.93	0.82	0.88	0.67	0.93	1.00	0.78
Heavy Vehicles (%)	0%	3%	1%	0%	3%	2%	7%	1%	3%	3%	1%	0%
Lane Group Flow (vph)	57	562	0	27	479	0	198	383	0	0	275	104
Turn Type	Perm			pm+pt			pm+pt			Perm		Perm
Protected Phases		4		3	8		1	6			2	
Permitted Phases	4			8			6			2		2
Total Split (s)	27.0	27.0	0.0	8.0	35.0	0.0	9.0	35.0	0.0	26.0	26.0	26.0
Act Effct Green (s)	23.2	23.2		28.7	26.1		31.1	31.1			22.1	22.1
Actuated g/C Ratio	0.36	0.36		0.41	0.40		0.48	0.48			0.34	0.34
v/c Ratio	0.34	0.96		0.14	0.73		0.46	0.48			0.91	0.19
Uniform Delay, d1	17.0	21.9		12.4	14.3		13.6	12.5			22.5	0.0
Delay	18.6	49.2		13.6	15.4		14.4	12.4			53.1	4.5
LOS	B	D		B	B		B	B			D	A
Approach Delay		46.3			15.3			13.1			39.8	
Approach LOS		D			B			B			D	
Queue Length 50th (ft)	15	191		5	142		40	83			95	0
Queue Length 95th (ft)	52	#447		16	243		85	178			#260	22
Internal Link Dist (ft)		860			1600			1344			1200	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)	75			75								
50th Bay Block Time %		41%			34%							
95th Bay Block Time %		62%			41%							
Queuing Penalty (veh)		29			10							

Intersection Summary

Cycle Length: 70

Actuated Cycle Length: 65.3

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.96

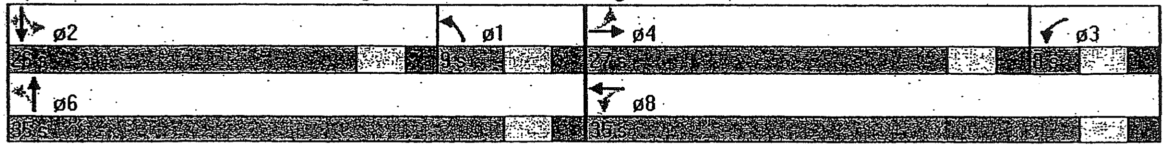
Intersection Signal Delay: 28.4 Intersection LOS: C

Intersection Capacity Utilization 83.1% ICU Level of Service D

\# 95th percentile volume exceeds capacity, queue may be longer.

Queue shown is maximum after two cycles.

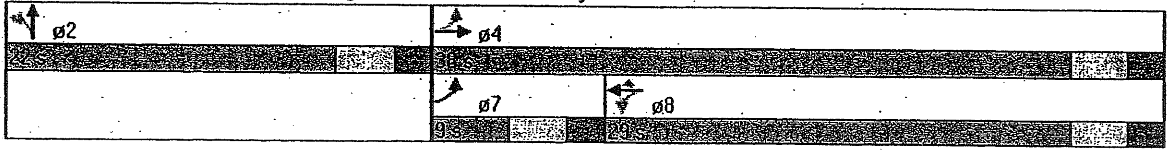
Splits and Phases: 16: Congress Street & Deering Avenue



	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↱			↰↑	↱	↰	↑↱				
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	0	3475	0	0	1825	1553	1805	1695	0	0	0	0
Flt Permitted		0.928			0.878		0.950					
Satd. Flow (perm)	0	3231	0	0	1612	1553	1805	1695	0	0	0	0
Satd. Flow (RTOR)		17				31		74				
Volume (vph)	21	501	32	64	440	30	58	146	118	0	0	0
Peak Hour Factor	0.79	0.98	1.00	1.00	0.96	0.58	0.79	0.91	0.85	0.92	0.92	0.92
Heavy Vehicles (%)	0%	3%	3%	0%	4%	4%	0%	1%	8%	2%	2%	2%
Lane Group Flow (vph)	0	570	0	0	522	52	73	299	0	0	0	0
Turn Type	pm+pt			Perm		Perm	Perm					
Protected Phases	7	4			8			2				
Permitted Phases	4			8		8	2					
Total Split (s)	9.0	38.0	0.0	29.0	29.0	29.0	22.0	22.0	0.0	0.0	0.0	0.0
Act Effct Green (s)		22.7			22.7	22.7	29.3	29.3				
Actuated g/C Ratio		0.38			0.38	0.38	0.49	0.49				
v/c Ratio		0.46			0.86	0.09	0.08	0.35				
Uniform Delay, d1		13.6			17.1	4.8	8.2	6.9				
Delay		13.3			20.6	6.3	9.5	8.0				
LOS		B			C	A	A	A				
Approach Delay		13.3			19.3			8.3				
Approach LOS		B			B			A				
Queue Length 50th (ft)		70			156	4	14	49				
Queue Length 95th (ft)		107			#308	11	29	97				
Internal Link Dist (ft)		776			968			870			1150	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)						50	125					
50th Bay Block Time %					43%							
95th Bay Block Time %					51%							
Queuing Penalty (veh)					24							

Intersection Summary
Cycle Length: 60
Actuated Cycle Length: 60
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:, Start of Green
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.86
Intersection Signal Delay: 14.3 Intersection LOS: B
Intersection Capacity Utilization 70.5% ICU Level of Service C
\# 95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 9: Congress Street & Valley Street



	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↱		↰		↱		↑↱			↰↑	
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	1787	3295	0	1626	0	1615	0	3502	0	0	3527	0
Flt Permitted	0.950			0.950							0.623	
Satd. Flow (perm)	1787	3295	0	1626	0	1615	0	3502	0	0	2210	0
Satd. Flow (RTOR)		235				171		5				
Volume (vph)	389	451	391	125	0	378	0	678	33	70	454	0
Peak Hour Factor	0.94	0.89	1.00	0.87	0.25	0.95	0.92	0.89	1.00	1.00	0.95	0.92
Heavy Vehicles (%)	1%	2%	3%	11%	0%	0%	0%	2%	13%	0%	2%	0%
Lane Group Flow (vph)	414	898	0	144	0	398	0	795	0	0	548	0
Turn Type	Prot			Prot		custom				custom		
Protected Phases	3	8		7		4		2		1	6	
Permitted Phases						4				1		
Total Split (s)	25.0	31.0	0.0	15.0	0.0	21.0	0.0	25.0	0.0	9.0	34.0	0.0
Act Effct Green (s)	20.5	25.6		10.6		15.6		31.9			31.9	
Actuated g/C Ratio	0.26	0.32		0.13		0.20		0.40			0.40	
v/c Ratio	0.90	0.74		0.67		0.88		0.57			0.62	
Uniform Delay, d1	28.8	17.4		33.1		17.5		18.6			19.2	
Delay	42.0	17.5		37.5		25.2		19.5			20.5	
LOS	D	B		D		C		B			C	
Approach Delay		25.2			28.4			19.5			20.5	
Approach LOS		C			C			B			C	
Queue Length 50th (ft)	198	149		69		110		164			116	
Queue Length 95th (ft)	#360	213		#135		#262		218			173	
Internal Link Dist (ft)		1004			776			849			1196	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)												
50th Bay Block Time %												
95th Bay Block Time %												
Queuing Penalty (veh)												

Intersection Summary

Cycle Length: 80

Actuated Cycle Length: 80

Offset: 0 (0%), Referenced to phase 2:NBT and 6:SBT, Start of Green

Control Type: Actuated-Coordinated

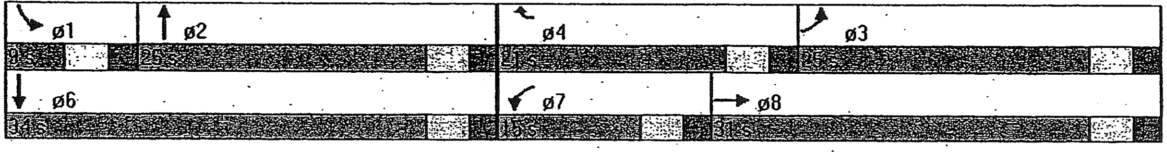
Maximum v/c Ratio: 0.90

Intersection Signal Delay: 23.5 Intersection LOS: C

Intersection Capacity Utilization 85.2% ICU Level of Service D

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 5: Congress Street & St. John Street

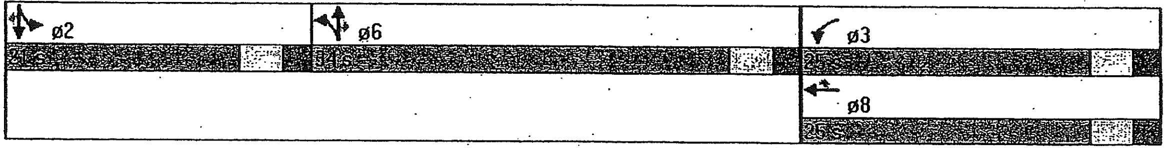


	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations					↰↑	↱	↖	↰	↱		↰	↱
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	0	0	0	0	3504	1599	1681	1746	1568	0	1872	1583
Flt Permitted					0.989		0.950	0.981			0.994	
Satd. Flow (perm)	0	0	0	0	3504	1599	1681	1746	1568	0	1872	1583
Satd. Flow (RTOR)						199			115			43
Volume (vph)	0	0	0	174	678	141	846	382	168	35	289	102
Peak Hour Factor	0.92	0.92	0.92	0.88	1.00	0.71	1.00	1.00	0.83	0.83	1.00	0.87
Heavy Vehicles (%)	2%	2%	2%	5%	1%	1%	2%	1%	3%	0%	1%	2%
Lane Group Flow (vph)	0	0	0	0	876	199	595	633	202	0	331	117
Turn Type				Prot		Perm	Split		Perm	Split		Perm
Protected Phases				3	8		6	6		2	2	
Permitted Phases						8			6			2
Total Split (s)	0.0	0.0	0.0	25.0	25.0	25.0	34.0	34.0	34.0	21.0	21.0	21.0
Act Effct Green (s)					21.0	21.0	30.0	30.0	30.0		16.5	16.5
Actuated g/C Ratio					0.26	0.26	0.38	0.38	0.38		0.21	0.21
v/c Ratio					0.95	0.35	0.94	0.96	0.30		0.85	0.32
Uniform Delay, d1					28.7	0.0	23.8	24.2	7.1		30.3	16.1
Delay					43.6	4.0	42.6	46.4	8.1		40.0	17.6
LOS					D	A	D	D	A		D	B
Approach Delay					36.2			39.4			34.1	
Approach LOS					D			D			C	
Queue Length 50th (ft)					226	0	296	320	28		159	30
Queue Length 95th (ft)					#346	20	#514	#547	63		#296	71
Internal Link Dist (ft)		1008			4636			1196			806	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)						200			100			
50th Bay Block Time %					12%			44%				
95th Bay Block Time %					37%			55%				
Queuing Penalty (veh)					48			100				

Intersection Summary

Cycle Length: 80
Actuated Cycle Length: 79.5
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 0.96
Intersection Signal Delay: 37.5   Intersection LOS: D
Intersection Capacity Utilization 85.5%   ICU Level of Service D
\# 95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 6: Park Avenue & St. John Street



17: Park Avenue & Deering Avenue

4/2/2004

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↱			↰↑	↱	↰	↑↱		↰	↑↱	
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	0	3168	0	0	3201	1425	1624	1617	0	1624	1617	0
Flt Permitted		0.791			0.862		0.613			0.200		
Satd. Flow (perm)	0	2523	0	0	2773	1425	1048	1617	0	342	1617	0
Satd. Flow (RTOR)		9				307		15			17	
Volume (vph)	46	274	21	67	540	270	90	263	67	97	174	49
Peak Hour Factor	0.89	0.89	1.00	0.88	0.80	0.88	0.88	1.00	0.95	1.00	0.95	0.98
Heavy Vehicles (%)	0%	1%	4%	1%	1%	2%	0%	3%	0%	0%	3%	0%
Lane Group Flow (vph)	0	381	0	0	751	307	102	334	0	97	233	0
Turn Type	Perm			Perm		Perm	pm+pt			pm+pt		
Protected Phases		4			8		1	6		5	2	
Permitted Phases	4			8		8	6			2		
Total Split (s)	45.0	45.0	0.0	45.0	45.0	45.0	10.0	30.0	0.0	15.0	35.0	0.0
Act Effct Green (s)		25.4			25.4	25.4	20.2	18.5		15.5	16.1	
Actuated g/C Ratio		0.40			0.40	0.40	0.31	0.29		0.24	0.25	
v/c Ratio		0.38			0.68	0.41	0.24	0.69		0.36	0.55	
Uniform Delay, d1		12.9			15.4	0.0	17.4	18.8		18.6	18.8	
Delay		14.6			17.1	2.2	22.6	22.8		23.7	23.3	
LOS		B			B	A	C	C		C	C	
Approach Delay		14.6			12.7			22.8			23.5	
Approach LOS		B			B			C			C	
Queue Length 50th (ft)		56			132	0	32	117		33	80	
Queue Length 95th (ft)		101			186	41	82	255		81	172	
Internal Link Dist (ft)		4636			1568			1200			904	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)						150	125			75		
50th Bay Block Time %								5%			13%	
95th Bay Block Time %					14%			39%		12%	43%	
Queuing Penalty (veh)					22			22		13	27	

Intersection Summary

Cycle Length: 90

Actuated Cycle Length: 63.6

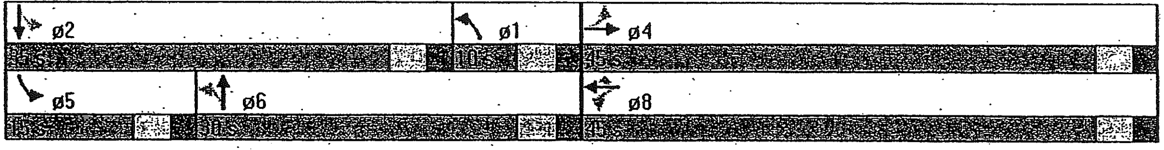
Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.69

Intersection Signal Delay: 16.6 Intersection LOS: B

Intersection Capacity Utilization 74.5% ICU Level of Service C

Splits and Phases: 17: Park Avenue & Deering Avenue



	↗	→	←	↖	↘	↙
Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations		↰	↱		Y	
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Volume (veh/h)	79	669	587	53	5	27
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00
Hourly flow rate (veh/h)	79	669	587	53	5	27
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type					None	
Median storage veh)						
Upstream signal (ft)						
pX, platoon unblocked						
vC, conflicting volume	640				1440	614
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	640				1440	614
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	92				96	95
cM capacity (veh/h)	954				135	496

Direction, Lane #	EB 1	WB 1	SB 1
Volume Total	748	640	32
Volume Left	79	0	5
Volume Right	0	53	27
cSH	954	1700	350
Volume to Capacity	0.08	0.38	0.09
Queue Length (ft)	7	0	7
Control Delay (s)	2.1	0.0	16.3
Lane LOS	A		C
Approach Delay (s)	2.1	0.0	16.3
Approach LOS			C

Intersection Summary			
Average Delay	1.5		
Intersection Capacity Utilization	87.0%	ICU Level of Service	D

HCM Unsignalized Intersection Capacity Analysis
27: Congress Street & Gilman Street

T:\317\Synchro\2007\2007 Pre PM.sy6
4/2/2004

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↱			↰		↖		↗		✥	
Sign Control		Free			Free			Stop			Stop	
Grade		0%			0%			0%			0%	
Volume (veh/h)	0	686	19	32	542	0	30	0	60	2	4	16
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Hourly flow rate (veh/h)	0	686	19	32	542	0	30	0	60	2	4	16
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)		1048										
pX, platoon unblocked				0.80			0.80	0.80	0.80	0.80	0.80	
vC, conflicting volume	542			705			1320	1302	696	1362	1311	542
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	542			630			1400	1378	619	1453	1390	542
tC, single (s)	4.1			4.1			7.1	6.5	6.2	7.1	6.5	6.2
tC, 2 stage (s)												
tF (s)	2.2			2.2			3.5	4.0	3.3	3.5	4.0	3.3
p0 queue free %	100			96			65	100	85	97	96	97
cM capacity (veh/h)	1037			764			86	112	392	72	110	544

Direction, Lane #	EB 1	WB 1	NB 1	NB 2	SB 1
Volume Total	705	574	30	60	22
Volume Left	0	32	30	0	2
Volume Right	19	0	0	60	16
cSH	1700	764	86	392	235
Volume to Capacity	0.41	0.04	0.35	0.15	0.09
Queue Length (ft)	0	3	34	13	8
Control Delay (s)	0.0	1.1	67.5	15.8	21.9
Lane LOS		A	F	C	C
Approach Delay (s)	0.0	1.1	33.0		21.9
Approach LOS			D		C

Intersection Summary			
Average Delay	3.0		
Intersection Capacity Utilization	71.1%	ICU Level of Service	C

HCM Unsignalized Intersection Capacity Analysis
30: Congress Street & EXISTING DRIVE

	↗	→	←	↖	↘	↙
Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations	↰	↑	↱		Y	
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Volume (veh/h)	87	572	581	34	21	98
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00
Hourly flow rate (veh/h)	87	572	581	34	21	98
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type					None	
Median storage veh)						
Upstream signal (ft)						
pX, platoon unblocked						
vC, conflicting volume	615				1344	598
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	615				1344	598
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	91				86	80
cM capacity (veh/h)	965				152	502

Direction, Lane #	EB 1	EB 2	WB 1	SB 1
Volume Total	87	572	615	119
Volume Left	87	0	0	21
Volume Right	0	0	34	98
cSH	965	1700	1700	357
Volume to Capacity	0.09	0.34	0.36	0.33
Queue Length (ft)	7	0	0	36
Control Delay (s)	9.1	0.0	0.0	20.0
Lane LOS	A			C
Approach Delay (s)	1.2		0.0	20.0
Approach LOS				C

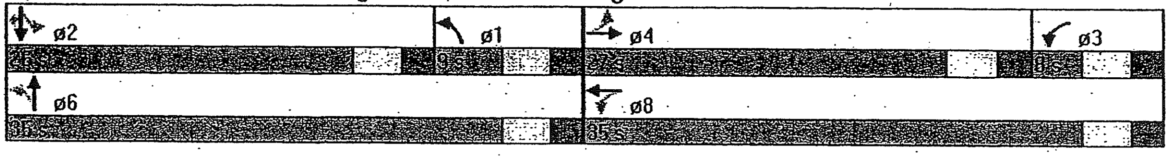
Intersection Summary			
Average Delay	2.3		
Intersection Capacity Utilization	54.7%	ICU Level of Service	A

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↱		↰	↱		↰	↱			↰	↱
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	1624	1622	0	1624	1590	0	1518	1651	0	0	1644	1454
Flt Permitted	0.270			0.156			0.485				0.533	
Satd. Flow (perm)	462	1622	0	267	1590	0	775	1651	0	0	895	1454
Satd. Flow (RTOR)		16			39			15				108
Volume (vph)	70	438	97	20	339	133	162	289	37	108	159	84
Peak Hour Factor	1.00	0.93	1.00	0.75	1.00	0.93	0.82	0.88	0.67	0.93	1.00	0.78
Heavy Vehicles (%)	0%	3%	1%	0%	3%	2%	7%	1%	3%	3%	1%	0%
Lane Group Flow (vph)	70	568	0	27	482	0	198	383	0	0	275	108
Turn Type	Perm			pm+pt			pm+pt			Perm		Perm
Protected Phases		4		3	8		1	6			2	
Permitted Phases	4			8			6			2		2
Total Split (s)	27.0	27.0	0.0	8.0	35.0	0.0	9.0	35.0	0.0	26.0	26.0	26.0
Act Effct Green (s)	23.2	23.2		28.7	26.2		31.1	31.1			22.1	22.1
Actuated g/C Ratio	0.36	0.36		0.41	0.40		0.48	0.48			0.34	0.34
v/c Ratio	0.43	0.97		0.14	0.73		0.46	0.48			0.91	0.19
Uniform Delay, d1	17.6	22.0		12.4	14.4		13.6	12.6			22.6	0.0
Delay	19.5	51.1		13.7	15.5		14.4	12.4			53.1	4.4
LOS	B	D		B	B		B	B			D	A
Approach Delay		47.7			15.4			13.1			39.4	
Approach LOS		D			B			B			D	
Queue Length 50th (ft)	19	194		5	143		40	84			95	0
Queue Length 95th (ft)	#65	#452		16	245		85	178			#260	22
Internal Link Dist (ft)		860			1600			1344			1200	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)	75			75								
50th Bay Block Time %		42%			34%							
95th Bay Block Time %		62%			41%							
Queuing Penalty (veh)		36			10							

Intersection Summary

Cycle Length: 70
Actuated Cycle Length: 65.3
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 0.97
Intersection Signal Delay: 28.9 Intersection LOS: C
Intersection Capacity Utilization 90.1% ICU Level of Service E
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 16: Congress Street & Deering Avenue



9: Congress Street & Valley Street

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↱			↰	↱	↰	↱				
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	0	3503	0	0	1824	1553	1805	1682	0	0	0	0
Flt Permitted		0.893			0.845		0.950					
Satd. Flow (perm)	0	3134	0	0	1552	1553	1805	1682	0	0	0	0
Satd. Flow (RTOR)						37		85				
Volume (vph)	21	533	0	90	504	43	58	146	134	0	0	0
Peak Hour Factor	0.79	0.98	1.00	1.00	0.96	0.58	0.79	0.91	0.85	0.92	0.92	0.92
Heavy Vehicles (%)	0%	3%	3%	0%	4%	4%	0%	1%	8%	2%	2%	2%
Lane Group Flow (vph)	0	571	0	0	615	74	73	318	0	0	0	0
Turn Type	pm+pt			Perm		Perm	Perm					
Protected Phases	7	4			8			2				
Permitted Phases	4			8		8	2					
Total Split (s)	9.0	38.0	0.0	29.0	29.0	29.0	22.0	22.0	0.0	0.0	0.0	0.0
Act Effct Green (s)		25.0			25.0	25.0	27.0	27.0				
Actuated g/C Ratio		0.42			0.42	0.42	0.45	0.45				
v/c Ratio		0.44			0.95	0.11	0.09	0.40				
Uniform Delay, d1		12.5			16.9	5.2	9.4	7.8				
Delay		12.8			36.4	6.6	9.7	8.2				
LOS		B			D	A	A	A				
Approach Delay		12.8			33.2			8.5				
Approach LOS		B			C			A				
Queue Length 50th (ft)		74			205	8	14	51				
Queue Length 95th (ft)		111			#401	15	29	103				
Internal Link Dist (ft)		776			968			870			1150	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)						50	125					
50th Bay Block Time %					47%							
95th Bay Block Time %					54%			2%				
Queuing Penalty (veh)					37							

Intersection Summary

Cycle Length: 60

Actuated Cycle Length: 60

Offset: 0 (0%), Referenced to phase 2:NBTL and 6:, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.95

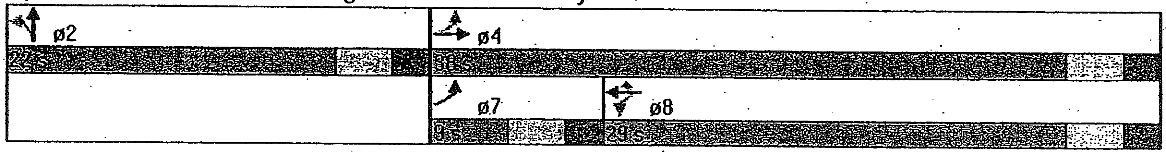
Intersection Signal Delay: 20.3 Intersection LOS: C

Intersection Capacity Utilization 76.5% ICU Level of Service C

\# 95th percentile volume exceeds capacity, queue may be longer.

Queue shown is maximum after two cycles.

Splits and Phases: 9: Congress Street & Valley Street



5: Congress Street & St. John Street

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↱		↰		↱		↑↱			↰↑	
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	1787	3299	0	1626	0	1615	0	3502	0	0	3524	0
Flt Permitted	0.950			0.950							0.594	
Satd. Flow (perm)	1787	3299	0	1626	0	1615	0	3502	0	0	2108	0
Satd. Flow (RTOR)		217				171		5				
Volume (vph)	389	472	391	150	0	417	0	678	33	81	454	0
Peak Hour Factor	0.94	0.89	1.00	0.87	0.25	0.95	0.92	0.89	1.00	1.00	0.95	0.92
Heavy Vehicles (%)	1%	2%	3%	11%	0%	0%	0%	2%	13%	0%	2%	0%
Lane Group Flow (vph)	414	921	0	172	0	439	0	795	0	0	559	0
Turn Type	Prot			Prot		custom				custom		
Protected Phases	3	8		7		24		2		1	6	
Permitted Phases						4				1		
Total Split (s)	25.0	31.0	0.0	15.0	0.0	21.0	0.0	25.0	0.0	9.0	34.0	0.0
Act Effct Green (s)	20.5	26.3		10.8		16.6		30.9			30.9	
Actuated g/C Ratio	0.26	0.33		0.14		0.21		0.39			0.39	
v/c Ratio	0.90	0.75		0.78		0.93		0.59			0.69	
Uniform Delay, d1	28.8	17.8		33.4		18.8		19.3			20.5	
Delay	42.0	18.1		45.5		37.1		19.9			21.5	
LOS	D	B		D		D		B			C	
Approach Delay		25.5			39.5			19.9			21.5	
Approach LOS		C			D			B			C	
Queue Length 50th (ft)	198	161		84		136		164			122	
Queue Length 95th (ft)	#360	226		#174		#313		218			182	
Internal Link Dist (ft)		1004			776			849			1196	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)												
50th Bay Block Time %												
95th Bay Block Time %												
Queuing Penalty (veh)												

Intersection Summary

Cycle Length: 80

Actuated Cycle Length: 80

Offset: 0 (0%), Referenced to phase 2:NBT and 6:SBT, Start of Green

Control Type: Actuated-Coordinated

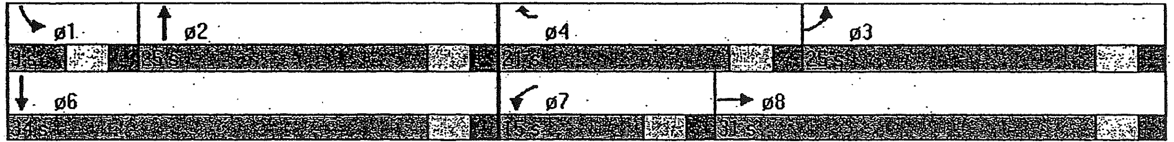
Maximum v/c Ratio: 0.93

Intersection Signal Delay: 26.1 Intersection LOS: C

Intersection Capacity Utilization 87.8% ICU Level of Service D

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 5: Congress Street & St. John Street



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations					↰↑	↱	↰	↰	↱		↰	↱
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	0	0	0	0	3504	1599	1681	1744	1568	0	1872	1583
Flt Permitted					0.989		0.950	0.980			0.994	
Satd. Flow (perm)	0	0	0	0	3504	1599	1681	1744	1568	0	1872	1583
Satd. Flow (RTOR)						199			111			40
Volume (vph)	0	0	0	174	691	141	879	388	168	35	300	102
Peak Hour Factor	0.92	0.92	0.92	0.88	1.00	0.71	1.00	1.00	0.83	0.83	1.00	0.87
Heavy Vehicles (%)	2%	2%	2%	5%	1%	1%	2%	1%	3%	0%	1%	2%
Lane Group Flow (vph)	0	0	0	0	889	199	614	653	202	0	342	117
Turn Type				Prot		Perm	Split		Perm	Split		Perm
Protected Phases				3	8		6	6		2	2	
Permitted Phases						8			6			2
Total Split (s)	0.0	0.0	0.0	25.0	25.0	25.0	34.0	34.0	34.0	21.0	21.0	21.0
Act Effct Green (s)					21.0	21.0	30.0	30.0	30.0		16.7	16.7
Actuated g/C Ratio					0.26	0.26	0.38	0.38	0.38		0.21	0.21
v/c Ratio					0.96	0.35	0.97	0.99	0.31		0.87	0.32
Uniform Delay, d1					28.9	0.0	24.4	24.8	7.4		30.4	17.2
Delay					46.4	4.0	49.0	54.1	8.4		43.1	18.5
LOS					D	A	D	D	A		D	B
Approach Delay					38.6			45.7			36.8	
Approach LOS					D			D			D	
Queue Length 50th (ft)					231	0	311	335	30		166	32
Queue Length 95th (ft)					#353	20	#536	#572	65		#309	73
Internal Link Dist (ft)		1008			4636			1196			806	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)						200			100			
50th Bay Block Time %					13%			45%				
95th Bay Block Time %					38%			55%				
Queuing Penalty (veh)					50			101				

Intersection Summary

Cycle Length: 80

Actuated Cycle Length: 79.7

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.99

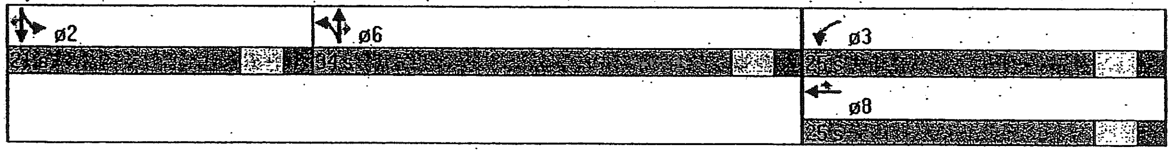
Intersection Signal Delay: 41.8 Intersection LOS: D

Intersection Capacity Utilization 87.5% ICU Level of Service D

\# 95th percentile volume exceeds capacity, queue may be longer.

Queue shown is maximum after two cycles.

Splits and Phases: 6: Park Avenue & St. John Street



	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↱			↰↑	↱	↰	↱		↰	↱	
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Satd. Flow (prot)	0	3168	0	0	3201	1425	1624	1612	0	1624	1617	0
Flt Permitted		0.790			0.857		0.613			0.200		
Satd. Flow (perm)	0	2520	0	0	2757	1425	1048	1612	0	342	1617	0
Satd. Flow (RTOR)		9				307		18			17	
Volume (vph)	46	274	21	70	540	270	90	263	80	97	174	49
Peak Hour Factor	0.89	0.89	1.00	0.88	0.80	0.88	0.88	1.00	0.95	1.00	0.95	0.98
Heavy Vehicles (%)	0%	1%	4%	1%	1%	2%	0%	3%	0%	0%	3%	0%
Lane Group Flow (vph)	0	381	0	0	755	307	102	347	0	97	233	0
Turn Type	Perm			Perm		Perm	pm+pt			pm+pt		
Protected Phases		4			8		1	6		5	2	
Permitted Phases	4			8		8	6			2		
Total Split (s)	45.0	45.0	0.0	45.0	45.0	45.0	10.0	30.0	0.0	15.0	35.0	0.0
Act Effct Green (s)		25.9			25.9	25.9	20.9	19.2		15.7	16.4	
Actuated g/C Ratio		0.40			0.40	0.40	0.31	0.30		0.24	0.25	
v/c Ratio		0.38			0.69	0.41	0.23	0.71		0.37	0.55	
Uniform Delay, d1		13.1			15.8	0.0	17.5	18.8		18.9	19.1	
Delay		14.8			17.4	2.2	22.7	24.0		24.2	23.8	
LOS		B			B	A	C	C		C	C	
Approach Delay		14.8			13.0			23.7			23.9	
Approach LOS		B			B			C			C	
Queue Length 50th (ft)		58			138	0	32	124		34	83	
Queue Length 95th (ft)		101			187	41	82	#272		82	173	
Internal Link Dist (ft)		4636			1568			1200			904	
50th Up Block Time (%)												
95th Up Block Time (%)												
Turn Bay Length (ft)						150	125			75		
50th Bay Block Time %					1%			8%			15%	
95th Bay Block Time %					14%			41%		12%	43%	
Queuing Penalty (veh)					22			25		14	28	

Intersection Summary

Cycle Length: 90

Actuated Cycle Length: 64.7

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.71

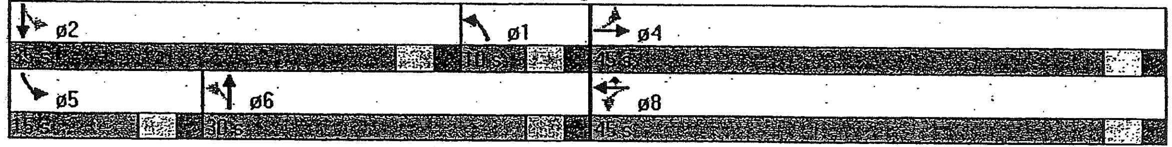
Intersection Signal Delay: 17.1 Intersection LOS: B

Intersection Capacity Utilization 75.5% ICU Level of Service C

\# 95th percentile volume exceeds capacity, queue may be longer.

Queue shown is maximum after two cycles.

Splits and Phases: 17: Park Avenue & Deering Avenue



12: Congress Street & Forest Street

4/2/2004

	↗	→	←	↖	↘	↙
Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations		↰	↱		Y	
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Volume (veh/h)	79	717	690	53	5	27
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00
Hourly flow rate (veh/h)	79	717	690	53	5	27
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type					None	
Median storage veh)						
Upstream signal (ft)						
pX, platoon unblocked						
vC, conflicting volume	743				1592	716
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	743				1592	716
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	91				95	94
cM capacity (veh/h)	873				109	433

Direction, Lane #	EB 1	WB 1	SB 1
Volume Total	796	743	32
Volume Left	79	0	5
Volume Right	0	53	27
cSH	873	1700	295
Volume to Capacity	0.09	0.44	0.11
Queue Length (ft)	7	0	9
Control Delay (s)	2.3	0.0	18.7
Lane LOS	A		C
Approach Delay (s)	2.3	0.0	18.7
Approach LOS			C

Intersection Summary			
Average Delay	1.5		
Intersection Capacity Utilization	95.0%	ICU Level of Service	E

HCM Unsignalized Intersection Capacity Analysis T:\1817\Synchro\2007\2007 Post PMrev3-2-04.sy6

27: Congress Street & Gilman Street 4/2/2004

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↱			↰		↰		↱		✥	
Sign Control		Free			Free			Stop			Stop	
Grade		0%			0%			0%			0%	
Volume (veh/h)	0	734	19	32	645	0	30	0	60	2	4	16
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Hourly flow rate (veh/h)	0	734	19	32	645	0	30	0	60	2	4	16
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)		1048										
pX, platoon unblocked				0.79			0.79	0.79	0.79	0.79	0.79	
vC, conflicting volume	645			753			1470	1452	744	1512	1462	645
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	645			688			1595	1572	676	1648	1584	645
tC, single (s)	4.1			4.1			7.1	6.5	6.2	7.1	6.5	6.2
tC, 2 stage (s)												
tF (s)	2.2			2.2			3.5	4.0	3.3	3.5	4.0	3.3
p0 queue free %	100			96			51	100	83	96	95	97
cM capacity (veh/h)	950			720			62	84	360	51	83	476

Direction, Lane #	EB 1	WB 1	NB 1	NB 2	SB 1
Volume Total	753	677	30	60	22
Volume Left	0	32	30	0	2
Volume Right	19	0	0	60	16
cSH	1700	720	62	360	181
Volume to Capacity	0.44	0.04	0.49	0.17	0.12
Queue Length (ft)	0	3	48	15	10
Control Delay (s)	0.0	1.2	109.6	17.0	27.6
Lane LOS		A	F	C	D
Approach Delay (s)	0.0	1.2	47.9		27.6
Approach LOS			E		D

Intersection Summary			
Average Delay	3.7		
Intersection Capacity Utilization	82.7%	ICU Level of Service	D

30: Congress Street & EXISTING DRIVE

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↱		↰	↑↱		↰		↱		✥	
Sign Control		Free			Free			Stop			Stop	
Grade		0%			0%			0%			0%	
Volume (veh/h)	87	572	48	6	581	34	103	0	19	21	0	98
Peak Hour Factor	1.00	1.00	0.60	0.60	1.00	1.00	0.60	0.60	0.60	1.00	1.00	1.00
Hourly flow rate (veh/h)	87	572	80	10	581	34	172	0	32	21	0	98
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	615			652			1485	1421	612	1396	1444	598
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	615			652			1485	1421	612	1396	1444	598
tC, single (s)	4.1			4.1			7.1	6.5	6.2	7.1	6.5	6.2
tC, 2 stage (s)												
tF (s)	2.2			2.2			3.5	4.0	3.3	3.5	4.0	3.3
p0 queue free %	91			99			0	100	94	80	100	80
cM capacity (veh/h)	965			935			76	123	493	103	119	502

Direction, Lane #	EB 1	EB 2	WB 1	WB 2	NB 1	NB 2	SB 1
Volume Total	87	652	10	615	172	32	119
Volume Left	87	0	10	0	172	0	21
Volume Right	0	80	0	34	0	32	98
cSH	965	1700	935	1700	76	493	298
Volume to Capacity	0.09	0.38	0.01	0.36	2.25	0.06	0.40
Queue Length (ft)	7	0	1	0	399	5	46
Control Delay (s)	9.1	0.0	8.9	0.0	687.6	12.8	24.9
Lane LOS	A		A		F	B	C
Approach Delay (s)	1.1		0.1		582.5		24.9
Approach LOS					F		C

Intersection Summary			
Average Delay	72.5		
Intersection Capacity Utilization	64.5%	ICU Level of Service	B

30: Congress Street & EXISTING DRIVE Performance by movement

	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBR	SBL	SBR
Total Delay (hr)	0.2	0.5	0.1	0.0	0.4	0.1	1.1	0.0	0.2	0.7
Delay / Veh (s)	7.7	2.9	5.9	1.8	2.5	5.2	37.1	5.3	37.6	23.7
Total Stops	46	0	0	0	0	2	108	20	20	110
Travel Dist (mi)	6.2	46.0	4.0	0.3	47.7	3.4	14.6	2.7	2.2	12.1
Travel Time (hr)	0.4	2.1	0.3	0.0	2.0	0.2	1.7	0.1	0.3	1.3
Avg Speed (mph)	15	22	15	20	24	17	9	19	7	10
Fuel Used (gal)	0.6	4.3	0.4	0.0	2.7	0.2	1.5	0.4	0.3	1.4
HC Emissions (g)	2	8	1	0	6	1	5	1	1	5
CO Emissions (g)	71	281	36	1	107	22	207	33	26	174
NOx Emissions (g)	6	27	4	0	11	2	17	2	3	13
Vehicles Entered	79	594	51	3	575	40	107	20	20	112
Vehicles Exited	79	599	51	3	576	40	110	20	22	114
Hourly Exit Rate	79	599	51	3	576	40	110	20	22	114
Denied Entry Before	0	0	0	0	0	0	1	0	0	0
Denied Entry After	0	0	0	0	0	0	0	0	0	0

30: Congress Street & EXISTING DRIVE Intersection Performance

	Total
Total Delay (hr)	3.3
Delay / Veh (s)	7.4
Total Stops	306
Travel Dist (mi)	139.2
Travel Time (hr)	8.4
Avg Speed (mph)	17
Fuel Used (gal)	11.7
HC Emissions (g)	29
CO Emissions (g)	958
NOx Emissions (g)	84
Vehicles Entered	1601
Vehicles Exited	1614
Hourly Exit Rate	1614
Denied Entry Before	1
Denied Entry After	0

Intersection: 17: Park Avenue & Deering Avenue

Movement	EB	EB	WB	WB	WB	NB	NB	SB	SB
Directions Served	LT	TR	LT	T	R	L	TR	L	TR
Maximum Queue (ft)	126	144	148	151	171	151	281	100	173
Average Queue (ft)	52	49	101	73	61	49	114	41	80
95th Queue (ft)	90	95	145	128	116	111	190	77	154
Link Distance (ft)	4623	4623	1614	1614			1202		931
Upstream Blk Time (%)									
Queuing Penalty (veh)									
Storage Bay Dist (ft)					150	125		75	
Storage Blk Time (%)				0.00	0.00	0.00	0.05	0.00	0.09
Queuing Penalty (veh)				1	0	0	5	0	8

Intersection: 27: Congress Street & Gilman Street

Movement	WB	NB	NB	SB
Directions Served	LT	L	R	LTR
Maximum Queue (ft)	425	68	109	51
Average Queue (ft)	31	25	30	18
95th Queue (ft)	134	52	66	47
Link Distance (ft)	920	926	926	1222
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 30: Congress Street & EXISTING DRIVE

Movement	EB	WB	NB	NB	SB
Directions Served	L	TR	L	R	LR
Maximum Queue (ft)	92	21	108	51	165
Average Queue (ft)	28	1	59	14	62
95th Queue (ft)	61	10	100	43	120
Link Distance (ft)	362	404	716	716	576
Upstream Blk Time (%)					
Queuing Penalty (veh)					
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Nework Summary

Network wide Queuing Penalty: 237

Appendix C

Collision Diagrams
Trip Generation Counts

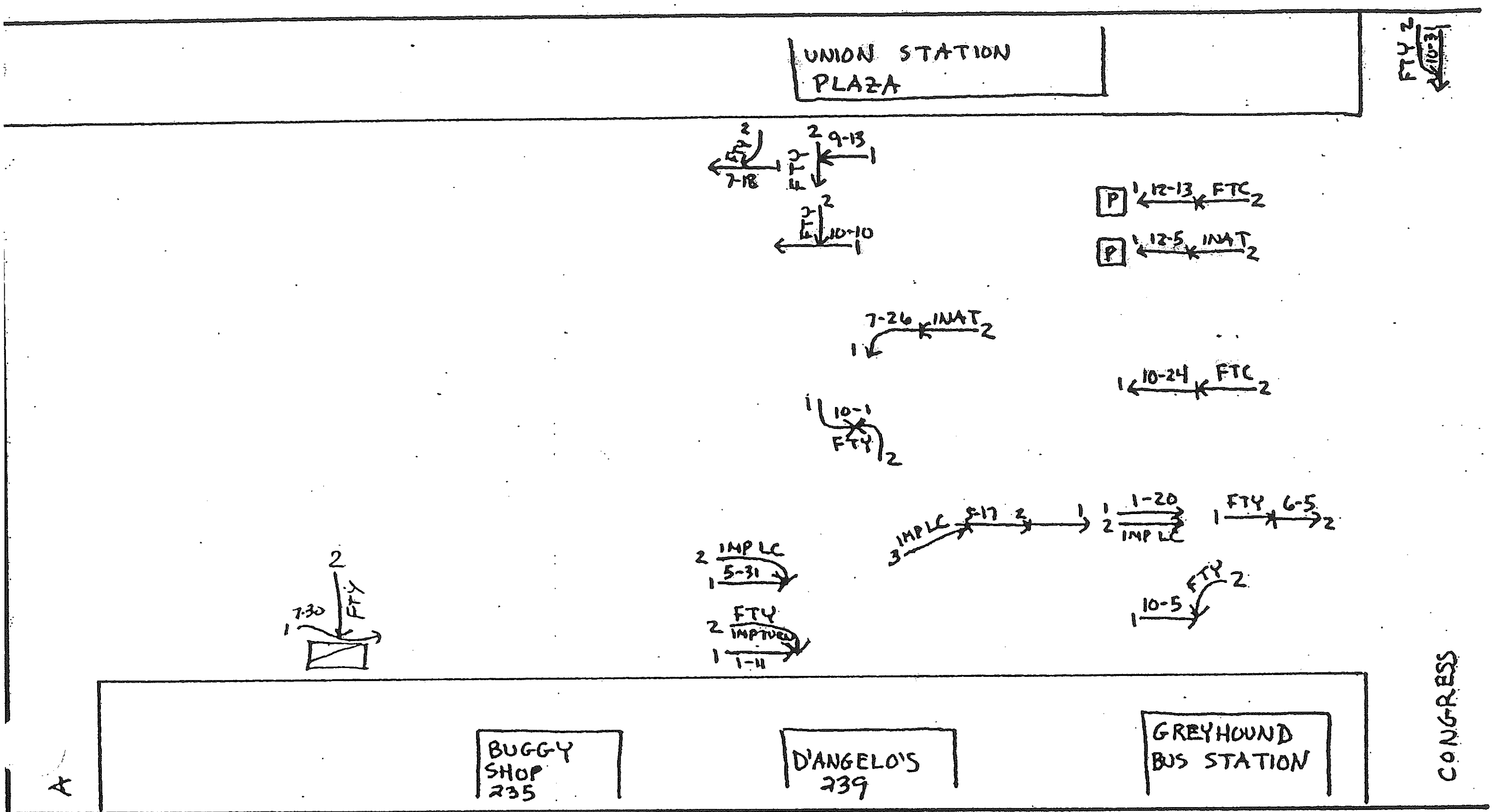
COLLISION DIAGRAM

SHEET 1 OF 2

OCATION St. JOHN STREET FROM A STREET TO CONGRESS STREET

1 PORTLAND NODE NO(S) 07181-07182

ARS REVIEWED 2000-2002 DATE PREPARED 8-4-03



CRITICAL RATE FACTOR 2.57 EQUIV. PROP. DAMAGE ACC/YEAR 16 ACCIDENTS ACC/MEV

LIGHT
1. DAWN (MORNING) 2. DAYLIGHT 3. DUSK (EVENING)
4. DARK (ST. LIGHTS ON) 5. DARK (NO ST. LIGHTS) 6. DARK (ST. LIGHTS OFF)
7. OTHER

ROAD SURFACE
1. DRY 2. WET 3. SNOW/SLUSH-SANDED
4. ICE/PACKED SNOW-SANDED 5. MUDDY 6. DEBRIS
7. OILY 8. SNOW/SLUSH-NOT SANDED 9. ICE/PKD. SNOW-NOT SANDED
10. OTHER

APPARENT CONTRIBUTING FACTORS - HUMAN
1. NO IMPROPER ACTION 2. FAIL TO YLD. RIGHT OF WAY 3. ILLEGAL UNSAFE SPEED
4. FOLLOW TOO CLOSE 5. DISREGARD TRAFFIC CONTROL DEVICE
6. DRIVING LEFT OF CENTER - NO PASSING 7. IMPROPER PASS-OVERTAKING
8. IMP. UNSAFE LANE CHANGE 9. IMP. PARKING START/STOP 10. IMPROPER TURN
11. UNSAFE BACKING 12. NO SIGNAL OR IMP. SIGNAL 13. IMPEDING TRAFFIC
14. DRIVER INATTENTION - DISTRACTION 15. DRIVER INEXPERIENCE
16. PEDEST. VIOLATION ERROR 17. PHYSICAL IMPAIRMENT 18. VISION OBSCURED - WINDSHIELD GLASS
19. VISION OBSCURED - SUN/HEADLIGHTS
20. OTHER VISION OBSCUREMENT 30. OTHER HUMAN VIOLATION FACTOR
31. HIT AND RUN 51. UNKNOWN

- VEHICULAR
41. DEFECTIVE BRAKES 42. DEFECTIVE TIRE/FAILURE 43. DEFECTIVE LIGHTS
44. DEFECTIVE SUSPENSION OR FACTOR 45. DEFECTIVE STEERING 50. OTHER VEHICLE DEFECT
51. UNKNOWN

SYMBOLS
ANGLE
BACKING
FIXED OBJECT
HEAD ON
OVERTURN
PARKED VEHICLE
PEDESTRIAN
REAR END
SIDE SWIPE
TURNING MOVE
CHANGE LANE
OUT OF CONTROL
FATAL ACCIDENT ●
VEHICLE (MOVING)
BICYCLE
ANIMAL
SLED

WEATHER
C = CLEAR
SL = SLEET
F = FOG
S = SNOW
R = RAIN
CL = CLOUDY
XW = CROSS WINDS

INJURIES
K = FATAL
A = INCAPACITATING
B = NON-INCAPACITATING
C = POSSIBLE INJURY

REPORT NO.	DATE	TIME	INJURIES K	A	B	C	LIGHT	ROAD SURFACE	ACF	OTHER
025019	12-13-02	21:32	—	—	—	—	DARK-4	WET-2	4	
022494	10-24-02	16:13	—	—	—	—	DAY-2	DRY-1	4	
0[illegible]2823	10-31-02	15:15	—	—	—	—	DAY-2	DRY-1	2	
[illegible]1788	7-26-02	13:00	—	—	—	2	DAY-2	DRY-1	14	
021457	10-01-02	13:15	—	—	—	—	DAY-2	DRY-1	2	
021678	10-5-02	20:13	—	—	2	—	DARK-4	DRY-1	30,2	
001316	1-11-02	19:00	—	—	—	—	DARK-4	WET-2	10	
024210	7-30-01	15:15	—	—	—	—	DAY-2	DRY-1	2	

COLLISION DIAGRAM

SHEET 2 OF 2

LOCATION St JOHN STREET FROM A TO CONGRESS STREET

N PORTLAND NODE NO(S) 07181-07182

YEARS REVIEWED 2000-2002 DATE PREPARED 8-4-03

REPORT NO.	DATE	TIME	INJURIES				LIGHT	ROAD SURFACE	ACF	OTHER
			K	A	B	C				
022637	9-13-01	15:50	—	—	—	—	DAY-2	DRY-1	2	
017882	6-5-01	16:25	—	—	—	—	DAY-2	DRY-1	2,14	
016054	5-17-01	15:20	—	—	—	—	DAY-2	DRY-1	8,4	
002764	1-20-00	18:30	—	—	—	—	DARK-4	WET-2	20,8	
00.38362	12-5-00	12:40	—	—	—	—	DAY-2	DRY-1	14	
00.16848	5-31-00	17:15	—	—	—	—	DAY-2	DRY-1	8	
00.31179	10-10-00	11:13	—	—	—	—	DAY-2	DRY-1	2,20	
00.22247	7-18-00	14:50	—	—	—	—	DAY-2	WET-2	20	

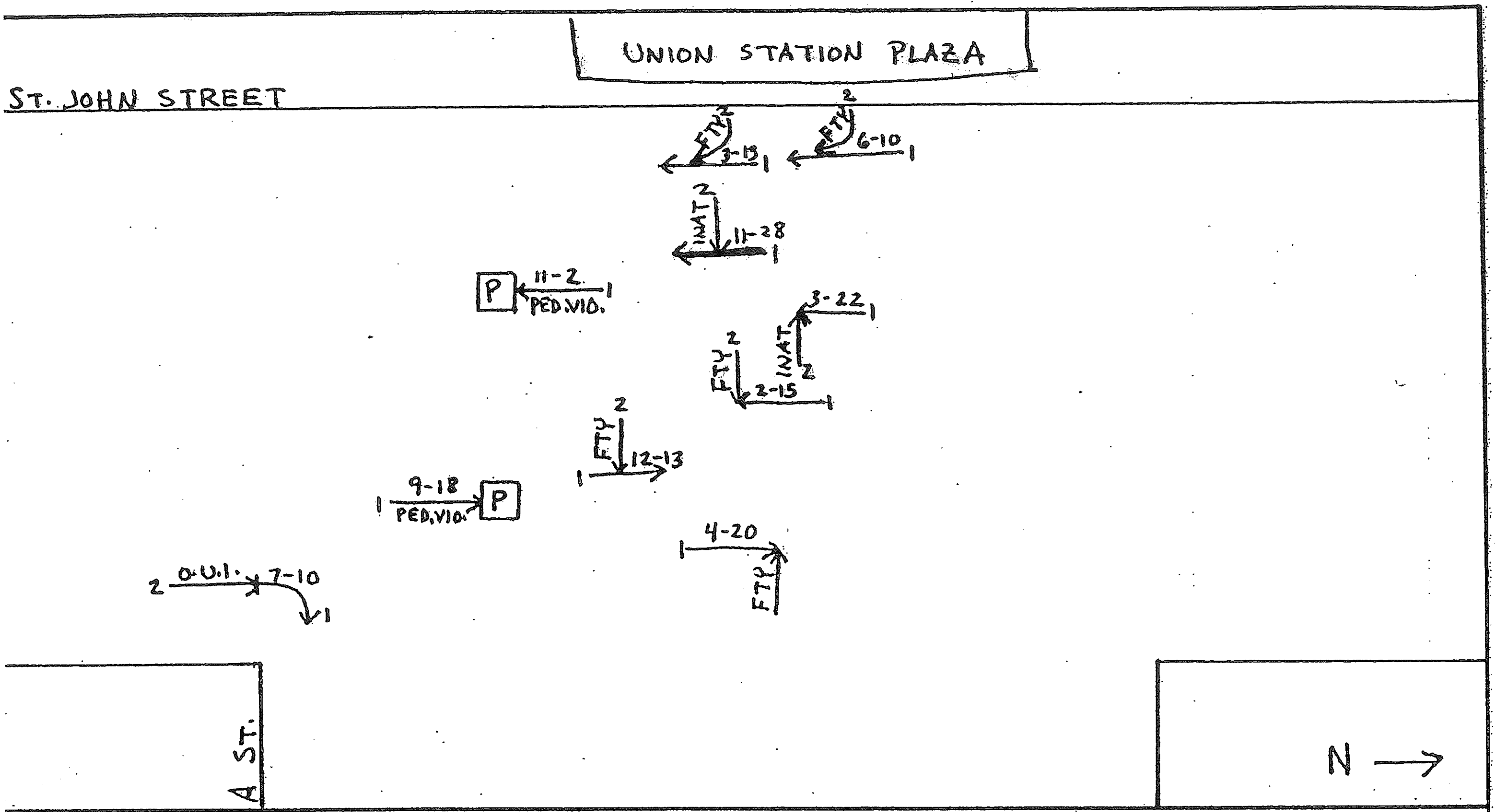
COLLISION DIAGRAM

SHEET 1 OF 2

OCATION St. John Street at A Street

PORTLAND NODE NO(S) 07181

RS REVIEWED 2000-2002 DATE PREPARED 8/6/03



CRITICAL RATE FACTOR 1.28 EQUIV. PROP. DAMAGE ACC/YEAR 10 ACCIDENTS ACC/MEV

LIGHT

1. DAWN (MORNING)
2. DAYLIGHT
3. DUSK (EVENING)
4. DARK (ST. LIGHTS ON)
5. DARK (NO ST. LIGHTS)
6. DARK (ST. LIGHTS OFF)
7. OTHER

ROAD SURFACE

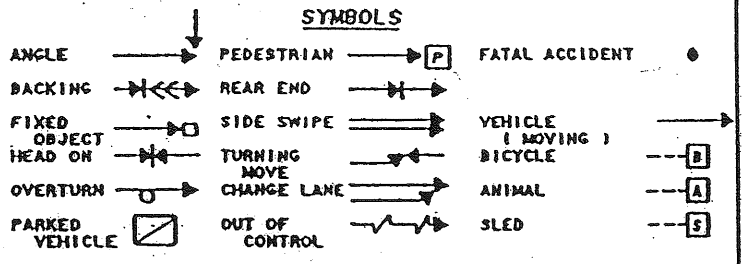
1. DRY
2. WET
3. SNOW/SLUSH-SANDED
4. ICE/PACKED SNOW-SANDED
5. MUDDY
6. DEBRIS
7. OILY
8. SNOW/SLUSH-NOT SANDED
9. ICE/PKD. SNOW-NOT SANDED
10. OTHER

APPARENT CONTRIBUTING FACTORS - HUMAN

1. NO IMPROPER ACTION
2. FAIL TO YLD. RIGHT OF WAY
3. ILLEGAL UNSAFE SPEED
4. FOLLOW TOO CLOSE
5. DISREGARD TRAFFIC CONTROL DEVICE
6. DRIVING LEFT OF CENTER - NO PASSING
7. IMPROPER PASS-OVERTAKING
8. IMP. UNSAFE LANE CHANGE
9. IMP. PARKING START/STOP
10. IMPROPER TURN
11. UNSAFE BACKING
12. NO SIGNAL OR IMP. SIGNAL
13. IMPEDING TRAFFIC
14. DRIVER INATTENTION - DISTRACTION
15. DRIVER INEXPERIENCE
16. PEDEST. VIOLATION ERROR
17. PHYSICAL IMPAIRMENT
18. VISION OBSCURED - WINDSHIELD GLASS
19. VISION OBSCURED - SUN/HEADLIGHTS
20. OTHER VISION OBSCUREMENT
30. OTHER HUMAN VIOLATION FACTOR
31. HIT AND RUN
51. UNKNOWN

- VEHICULAR

41. DEFECTIVE BRAKES
42. DEFECTIVE TIRE/FAILURE
43. DEFECTIVE LIGHTS
44. DEFECTIVE SUSPENSION OR FACTOR
48. DEFECTIVE STEERING
50. OTHER VEHICLE DEFECT
51. UNKNOWN



WEATHER

C = CLEAR
SL = SLEET
F = FOG
S = SNOW
R = RAIN
CL = CLOUDY
XW = CROSS WINDS

INJURIES

K = FATAL
A = INCAPACITATING
B = NON-INCAPACITATING
C = POSSIBLE INJURY

REPORT NO.	DATE	TIME	INJURIES				LIGHT	ROAD SURFACE	ACF	OTHER
			K	A	B	C				
004003	3/22/02	16:50	—	—	—	—	DAY-2	DRY-1	14	
025012	12/13/02	9:30	—	—	—	—	DAY-2	WET-2	2,19	
0010065	2/15/01	11:12	—	—	—	2	DAY-2	DRY-1	2	
09680	3/13/00	14:56	—	—	—	—	DAY-2	DRY-1	2	
00.12953	4/20/00	12:00	—	—	—	—	DAY-2	DRY-1	2	
00.17749	6/10/00	14:15	—	—	—	—	DAY-2	DRY-1	20,7	
00.21017	7/10/00	14:13	—	—	—	—	DAY-2	DRY-1	4,17	O.U.I *
00.28999	9/18/00	21:08	—	1	—	—	DARK-4	DRY-1	16	

COLLISION DIAGRAM

SHEET 2 OF 2

OCATION ST. JOHN STREET AT A STREET

Y PORTLAND NODE NO(S) 07181

YEARS REVIEWED 2000-2002 DATE PREPARED 8/6/03

REPORT NO.	DATE	TIME	INJURIES K	INJURIES A	INJURIES B	INJURIES C	LIGHT	ROAD SURFACE	ACF	OTHER
00.33935	11/2/00	17:19	—	—	1	—	DARK-5	DRY-1	16	
00.37626	11/28/00	15:30	—	—	—	—	DUSK-3	DRY-1	14	

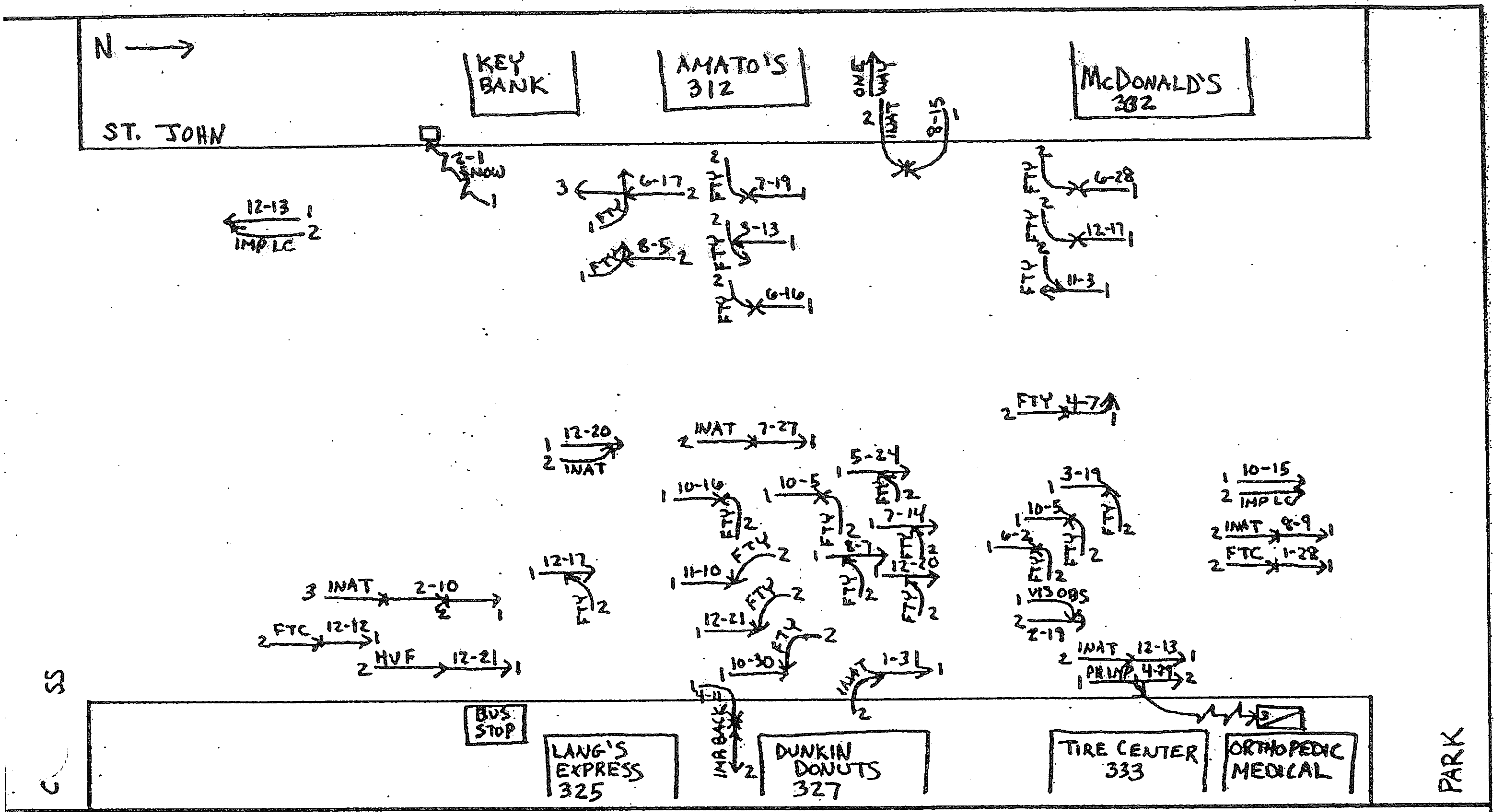
COLLISION DIAGRAM

SHEET 1 OF 2

OCATION ST. JOHN STREET FROM CONGRESS ST. TO PARK AVE

PORTLAND NODE NO(S) 07182-07187

RS REVIEWED 2000-2002 DATE PREPARED 8/4/03



CRITICAL RATE FACTOR 3.03 EQUIV. PROP. DAMAGE ACC/YEAR 38 ACCIDENTS ACC/MEV

LIGHT

1. DAWN (MORNING) 2. DAYLIGHT 3. DUSK (EVENING)
4. DARK (ST. LIGHTS ON) 5. DARK (NO ST. LIGHTS) 6. DARK (ST. LIGHTS OFF)
7. OTHER

ROAD SURFACE

1. DRY 2. WET 3. SNOW/SLUSH-SANDED
4. ICE/PACKED SNOW-SANDED 5. MUDDY 6. DEBRIS
7. OILY 8. SNOW/SLUSH-NOT SANDED 9. ICE/PKD. SNOW-NOT SANDED
10. OTHER

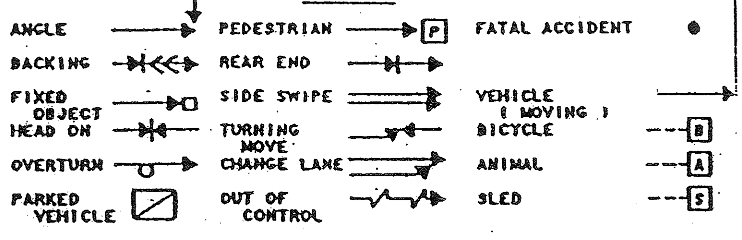
APPARENT CONTRIBUTING FACTORS - HUMAN

1. NO IMPROPER ACTION 2. FAIL TO YLD. RIGHT OF WAY 3. ILLEGAL UNSAFE SPEED
4. FOLLOW TOO CLOSE 5. DISREGARD TRAFFIC CONTROL DEVICE
6. DRIVING LEFT OF CENTER - NO PASSING 7. IMPROPER PASS-OVERTAKING
8. IMP. UNSAFE LANE CHANGE 9. IMP. PARKING START/STOP 10. IMPROPER TURN
11. UNSAFE BACKING 12. NO SIGNAL OR IMP. SIGNAL 13. IMPEDING TRAFFIC
14. DRIVER INATTENTION - DISTRACTION 15. DRIVER INEXPERIENCE
16. PEDEST. VIOLATION ERROR 17. PHYSICAL IMPAIRMENT 18. VISION OBSCURED - WINDSHIELD GLASS
19. VISION OBSCURED - SUN/HEADLIGHTS
20. OTHER VISION OBSCUREMENT 30. OTHER HUMAN VIOLATION FACTOR
31. HIT AND RUN 51. UNKNOWN

- VEHICULAR

41. DEFECTIVE BRAKES 42. DEFECTIVE TIRE/FAILURE 43. DEFECTIVE LIGHTS
44. DEFECTIVE SUSPENSION OR FACTOR 45. DEFECTIVE STEERING 50. OTHER VEHICLE DEFECT
51. UNKNOWN

SYMBOLS



WEATHER

C = CLEAR
SL = SLEET
F = FOG
S = SNOW
R = RAIN
CL = CLOUDY
XW = CROSS WINDS

INJURIES

K = FATAL
A = INCAPACITATING
B = NON-INCAPACITATING
C = POSSIBLE INJURY

REPORT NO.	DATE	TIME	INJURIES K	A	B	C	LIGHT	ROAD SURFACE	ACF	OTHER
014772	6-17-02	10:43	—	—	—	—	DAY-2	DRY-1	2	
018533	8-5-02	20:05	—	—	—	1	DARK-4	DRY-1	10	
025021	12-13-02	13:00	—	—	—	—	DAY-2	DRY-1	14	
376	6-28-02	12:07	—	—	—	2	DAY-2	DRY-1	14, 2	
002886	3-19-02	8:06	—	—	—	—	DAY-2	WET-2	2	
011073	4-29-02	14:42	—	—	—	1	DAY-2	WET-2	17	(SEIZURE)
006056	1-31-02	8:30	—	—	—	1	DAY-2	DRY-1	14	
032146	10-15-01	8:27	—	—	—	—	DAY-2	WET-2	8	

COLLISION DIAGRAM

SHEET 2 OF 2

OCATION St John Street from Congress St. to Park Ave

Portland NODE NO(S) 07182-07187

ARS REVIEWED 2000-2002 DATE PREPARED 8/4/03

EPORT NO.	DATE	TIME	INJURIES				LIGHT	ROAD SURFACE	ACF	OTHER
			K	A	B	C				
30973	10-5-01	12:28	—	—	—	—	DAY-2	DRY-1	2	
30999	10-5-01	7:05	—	—	—	—	DAY-2	DRY-1	2,14	
33755	10-30-01	13:06	—	—	—	1	DAY-2	DRY-1	2	
27205	8-7-01	18:40	—	—	—	—	DAY-2	DRY-1	2,13	
27444	8-9-01	17:56	—	—	—	—	DAY-2	DRY-1	14	
25773	7-27-01	17:25	—	—	—	—	DAY-2	DRY-1	14	
40045	12-17-01	16:34	—	—	—	—	DUSK-3	ICE-9	2,13	
41182	12-21-01	13:37	—	—	—	—	DAY-2	DRY-1	2	
39534	12-13-01	13:00	—	—	—	—	DAY-2	WET-2	10	
40949	12-20-01	10:40	—	—	—	—	DAY-2	DRY-1	2	
40041	12-17-01	15:30	—	—	—	—	DUSK-3	SNOW-3	3	
40944	12-20-01	19:25	—	—	—	—	DARK-4	DRY-1	14	
24754	7-19-01	8:15	—	—	—	—	DAY-2	DRY-1	14,2	
1 445	4-7-01	13:10	—	—	—	1	DAY-2	DRY-1	2	
74	3-13-01	7:30	—	—	—	—	DAY-2	SNOW-3	14	
1 809	4-11-01	8:00	—	—	—	—	DAY-2	DRY-1	11,14	
06379	2-19-01	12:14	—	—	—	—	DAY-2	DRY-1	20	
04146	2-1-01	20:20	—	—	—	—	DARK-4	WET-2	14	R,S
0.40021	11-3-00	17:30	—	—	—	—	DARK-4	DRY-1	2	
0.39268	12-12-00	13:03	—	—	1	—	DAY-2	DRY-1	4	
0.34708	11-10-00	19:10	—	—	—	—	DARK-4	WET-2	2	
0.40449	12-21-00	13:11	—	—	—	—	DAY-2	DRY-1	30	
0.18313	6-16-00	11:58	—	—	—	—	DAY-2	DRY-1	20,2	
0.21544	7-14-00	11:50	—	—	—	—	DAY-2	DRY-1	2,14	
00.16103	5-24-00	16:27	—	—	—	—	DAY-2	WET-2	20,2	
00.05875	2-10-00	12:50	—	—	—	1	DAY-2	WET-2	14	
00.17012	6-2-00	17:10	—	—	1	—	DAY-2	DRY-1	20	
00.04561	1-28-00	16:45	—	—	—	—	DAY-2	ICE-4	4	
00.31703	10-16-00	15:35	—	—	—	2	DAY-2	WET-2	10	
00.25205	8-15-00	22:19	—	—	—	—	DARK-6	WET-2	14	

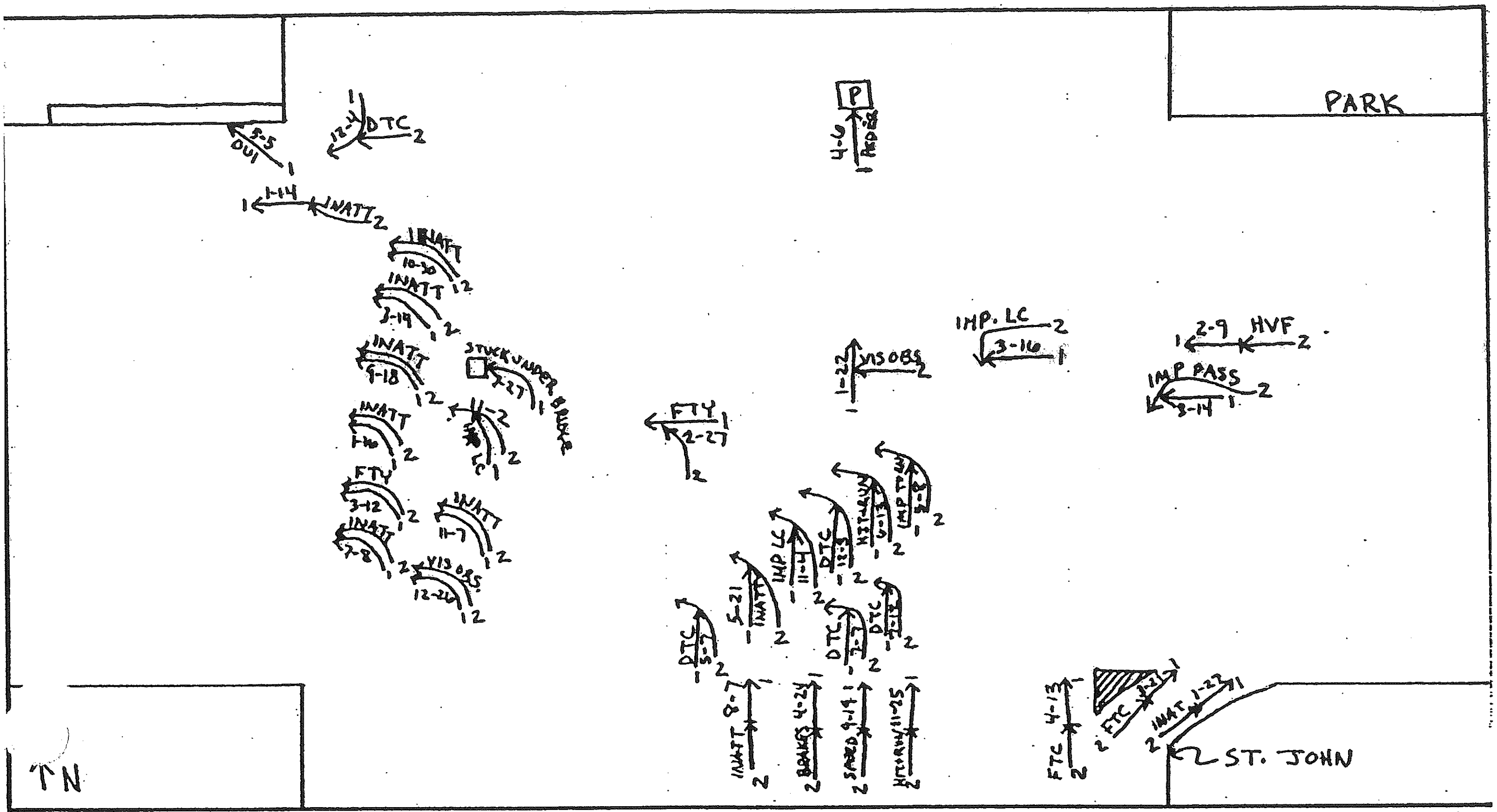
COLLISION DIAGRAM

SHEET 1 OF 2

OCATION ST. JOHN STREET AT PARK AVENUE

Y PORTLAND NODE NO(S) 07187

EARS REVIEWED 2000 - 2002 DATE PREPARED 8/4/03



CRITICAL RATE FACTOR 1.01 EQUIV. PROP. DAMAGE ACC/YEAR 34 ACCIDENTS ACC/MEV

LIGHT

1. DAWN (MORNING) 2. DAYLIGHT 3. DUSK (EVENING)
4. DARK (ST. LIGHTS ON) 5. DARK (NO ST. LIGHTS) 6. DARK (ST. LIGHTS OFF)
7. OTHER

ROAD SURFACE

1. DRY 2. WET 3. SNOW/SLUSH-SANDED
4. ICE/PACKED SNOW-SANDED 5. MUDDY 6. DEBRIS
7. OILY 8. SNOW/SLUSH-NOT SANDED 9. ICE/PKD. SNOW-NOT SANDED
10. OTHER

APPARENT CONTRIBUTING FACTORS - HUMAN

1. NO IMPROPER ACTION 2. FAIL TO YLD. RIGHT OF WAY 3. ILLEGAL UNSAFE SPEED
4. FOLLOW TOO CLOSE 5. DISREGARD TRAFFIC CONTROL DEVICE
6. DRIVING LEFT OF CENTER - NO PASSING 7. IMPROPER PASS-OVERTAKING
8. IMP. UNSAFE LANE CHANGE 9. IMP. PARKING START/STOP 10. IMPROPER TURN
11. UNSAFE BACKING 12. NO SIGNAL OR IMP. SIGNAL 13. IMPEDING TRAFFIC
14. DRIVER INATTENTION - DISTRACTION 15. DRIVER INEXPERIENCE
16. PEDEST. VIOLATION ERROR 17. PHYSICAL IMPAIRMENT 18. VISION OBSCURED - WINDSHIELD GLASS
19. VISION OBSCURED - SUN/HEADLIGHTS
20. OTHER VISION OBSCUREMENT 30. OTHER HUMAN VIOLATION FACTOR
31. HIT AND RUN 51. UNKNOWN

- VEHICULAR

41. DEFECTIVE BRAKES 42. DEFECTIVE TIRE/FAILURE 43. DEFECTIVE LIGHTS
44. DEFECTIVE SUSPENSION OR FACTOR 45. DEFECTIVE STEERING 50. OTHER VEHICLE DEFECT
51. UNKNOWN

SYMBOLS

ANGLE →
PEDESTRIAN → P
FATAL ACCIDENT ●
BACKING
REAR END
FIXED OBJECT → □
SIDE SWIPE
VEHICLE (MOVING) →
HEAD ON
TURNING MOVE
BICYCLE - - - B
OVERTURN
CHANGE LANE
ANIMAL - - - A
PARKED VEHICLE ▨
OUT OF CONTROL
SLED - - - S

WEATHER

C = CLEAR
SL = SLEET
F = FOG
S = SNOW
R = RAIN
CL = CLOUDY
XW = CROSS WINDS

INJURIES

K = FATAL
A = INCAPACITATING
B = NON-INCAPACITATING
C = POSSIBLE INJURY

REPORT NO.	DATE	TIME	INJURIES K	A	B	C	LIGHT	ROAD SURFACE	ACF	OTHER
020871	9-18-02	15:00	—	—	—	—	DAY-2	DRY-1	14	
013971	5-21-02	22:00	—	—	—	—	DARK-4	DRY-1	14	
9381	2-27-02	22:21	—	—	—	—	DARK-4	WET-2	2, 5	
1415	5-5-02	00:58	—	—	1	—	DARK-4	DRY-1	17	O.U.I.
001809	1-14-02	12:28	—	—	—	—	DAY-2	WET-2	14	
002797	3-16-02	12:36	—	—	—	—	DAY-2	WET-2	8	
003115	1-16-02	19:35	—	—	—	—	DARK-4	DRY-1	14	
002444	3-14-02	16:40	—	—	—	—	DAY-2	DRY-1	14	

COLLISION DIAGRAM

SHEET 2 OF 2

OCATION ST. JOHN STREET AT PARK AVENUE

PORTLAND NODE NO(S) 07187

EARS REVIEWED 2000-2002 DATE PREPARED 8/4/03

REPORT NO.	DATE	TIME	INJURIES K	A	B	C	LIGHT	ROAD SURFACE	ACF	OTHER
027196	8-7-01	17:28	—	—	1	1	DAY-2	DRY-1	14	
005360	2-9-01	12:45	—	—	—	—	DAY-2	ICE-9	30	
012958	4-13-01	16:50	—	—	—	—	DAY-2	DRY-1	4,14	
012336	4-6-01	19:38	—	—	—	1	DARK-4	WET-2	16	
009060	3-12-01	15:20	—	—	—	—	DAY-2	WET-2	2	
003547	1-27-01	10:00	—	—	—	—	DAY-2	DRY-1	15,14	
022238	7-8-01	19:40	—	—	—	—	DAY-2	DRY-1	14	
034313	11-4-01	15:15	—	—	—	—	DAY-2	DRY-1	8,14	
033731	10-30-01	14:50	—	—	—	2	DAY-2	DRY-1	4	
038044	12-3-01	9:35	—	—	—	—	DAY-2	DRY-1	5	
018748	6-13-01	15:00	—	—	—	—	DAY-2	DRY-1	31	
00.33937	11-2-00	16:34	—	—	—	—	DUSK-3	DRY-1	8,20	
00.23046	7-27-00	11:38	—	—	—	—	DAY-2	WET-2	30	
0[illegible] 03773	1-22-00	15:17	—	—	—	1	DAY-2	DRY-1	19	
09781	3-14-00	9:00	—	—	—	—	DAY-2	DRY-1	7	
00.10628	3-21-00	9:20	—	—	—	—	DAY-2	DRY-1	4	
00.13400	4-24-00	9:13	—	—	—	1	DAY-2	DRY-1	30,41	
00.14671	5-7-00	9:34	—	—	—	—	DAY-2	DRY-1	5,14	
00.14744	5-8-00	14:21	—	—	—	—	DAY-2	DRY-1	5,10	
00.20778	7-7-00	9:40	—	—	—	—	DAY-2	DRY-1	5	
00.21300	7-12-00	17:58	—	—	—	—	DAY-2	DRY-1	5	
00.32431	9-19-00	19:19	—	—	—	1	DARK-4	DRY-1	3,31	
00.34355	11-7-00	14:04	—	—	—	—	DAY-2	DRY-1	30	
00.40051	11-25-00	23:30	—	—	—	—	DARK-4	OIL-7	31	
00.38243	12-4-00	12:57	—	—	3	—	DAY-2	DRY-1	5	
00.41288	12-26-00	13:16	—	—	—	—	DAY-2	DRY-1	30	

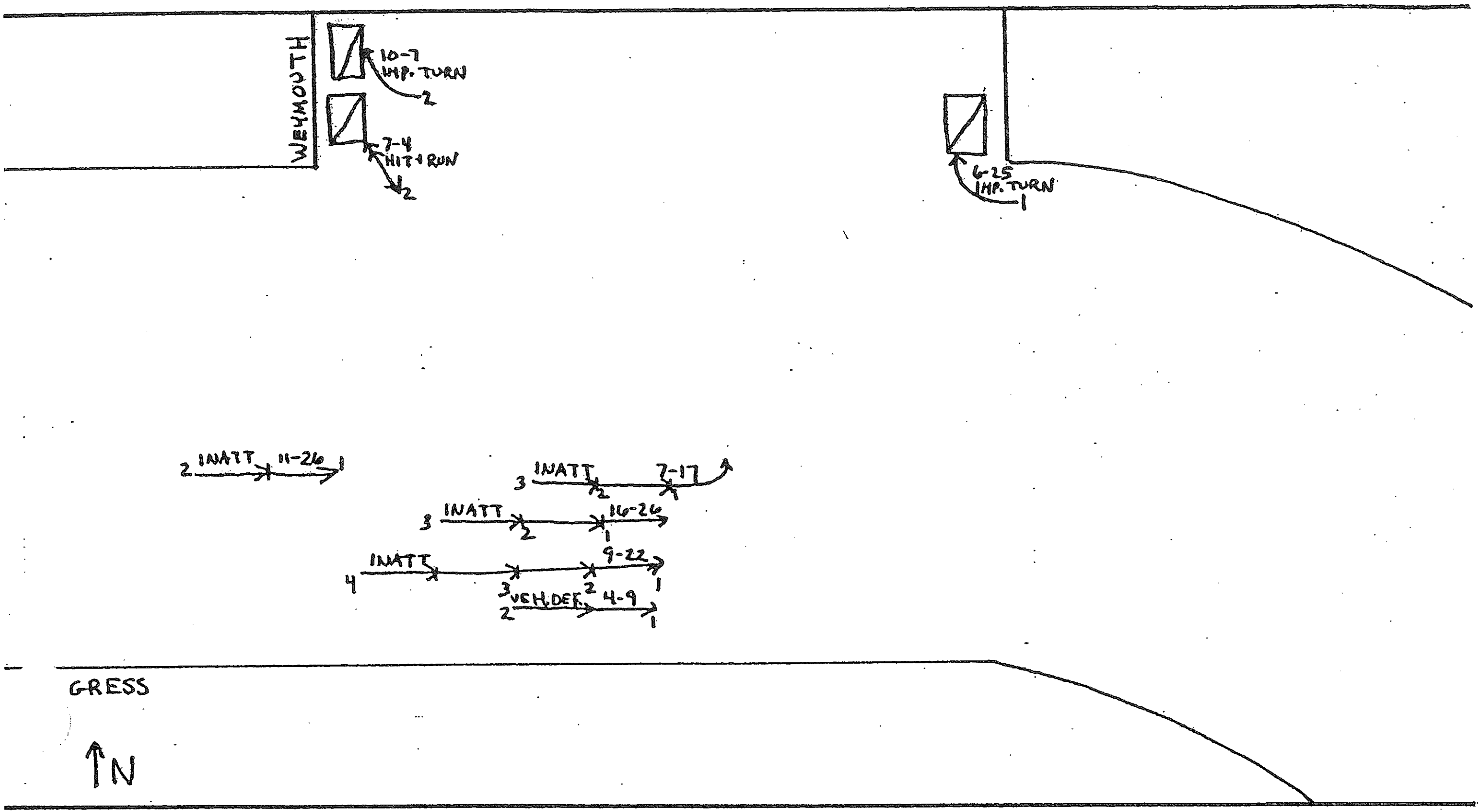
COLLISION DIAGRAM

SHEET 1 OF 1

OCATION Congress Street at Weymouth Street

Portland NODE NO(S) 07245

EARS REVIEWED 2000-2002 DATE PREPARED 8/4/03



CRITICAL RATE FACTOR 1.00 EQUIV. PROP. DAMAGE ACC/YEAR 8 ACCIDENTS ACC/MEV

LIGHT

1. DAWN (MORNING)	2. DAYLIGHT	3. DUSK (EVENING)
4. DARK (ST. LIGHTS ON)	5. DARK (NO ST. LIGHTS)	6. DARK (ST. LIGHTS OFF)
7. OTHER		

ROAD SURFACE

1. DRY	2. WET	3. SNOW/SLUSH-SANDED
4. ICE/PACKED SNOW-SANDED	5. MUDDY	6. DEBRIS
7. OILY	8. SNOW/SLUSH-NOT SANDED	9. ICE/PKD. SNOW-NOT SANDED
10. OTHER		

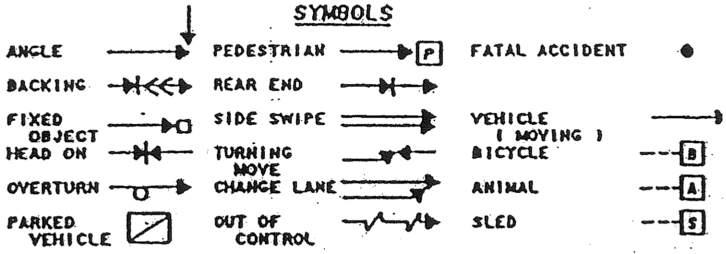
APPARENT CONTRIBUTING FACTORS - HUMAN

1. NO IMPROPER ACTION	2. FAIL TO YLD. RIGHT OF WAY	3. ILLEGAL UNSAFE SPEED
4. FOLLOW TOO CLOSE	5. DISREGARD TRAFFIC CONTROL DEVICE	
6. DRIVING LEFT OF CENTER - NO PASSING		7. IMPROPER PASS-OVERTAKING
8. IMP. UNSAFE LANE CHANGE	9. IMP. PARKING START/STOP	10. IMPROPER TURN
11. UNSAFE BACKING	12. NO SIGNAL OR IMP. SIGNAL	13. IMPEDING TRAFFIC
14. DRIVER INATTENTION - DISTRACTION		15. DRIVER INEXPERIENCE
16. PEDEST. VIOLATION ERROR	17. PHYSICAL IMPAIRMENT	18. VISION OBSCURED - WINDSHIELD GLASS
	19. VISION OBSCURED - SUN/HEADLIGHTS	
20. OTHER VISION OBSCUREMENT	30. OTHER HUMAN VIOLATION FACTOR	
31. HIT AND RUN	51. UNKNOWN	

- VEHICULAR

41. DEFECTIVE BRAKES	42. DEFECTIVE TIRE/FAILURE	43. DEFECTIVE LIGHTS
44. DEFECTIVE SUSPENSION OR FACTOR	45. DEFECTIVE STEERING	50. OTHER VEHICLE DEFECT
	51. UNKNOWN	

SYMBOLS



WEATHER

C = CLEAR	F = FOG	R = RAIN
SL = SLEET	S = SNOW	Cl = CLOUDY
		XW = CROSS WINDS

INJURIES

K = FATAL	B = NON-INCAPACITATING
A = INCAPACITATING	C = POSSIBLE INJURY

REPORT NO.	DATE	TIME	INJURIES				LIGHT	ROAD SURFACE	ACF	OTHER
			K	A	B	C				
017205	7-17-02	14:35	—	—	—	1	DAY-2	DRY-1	14	
016142	6-25-02	15:50	—	—	—	—	DAY-2	DRY-1	10	
7065	11-26-01	16:15	—	—	—	1	DUSK-3	DRY-1	14	
1029	7-4-01	18:43	—	—	—	—	DAY-2	DRY-1	31	
020215	16-26-01	16:49	—	—	—	1	DAY-2	DRY-1	14	
00.29319	9-22-00	15:30	—	—	—	3	DAY-2	DRY-1	14	
00.12087	4-9-00	16:32	—	—	—	—	DAY-2	DRY-1	50	

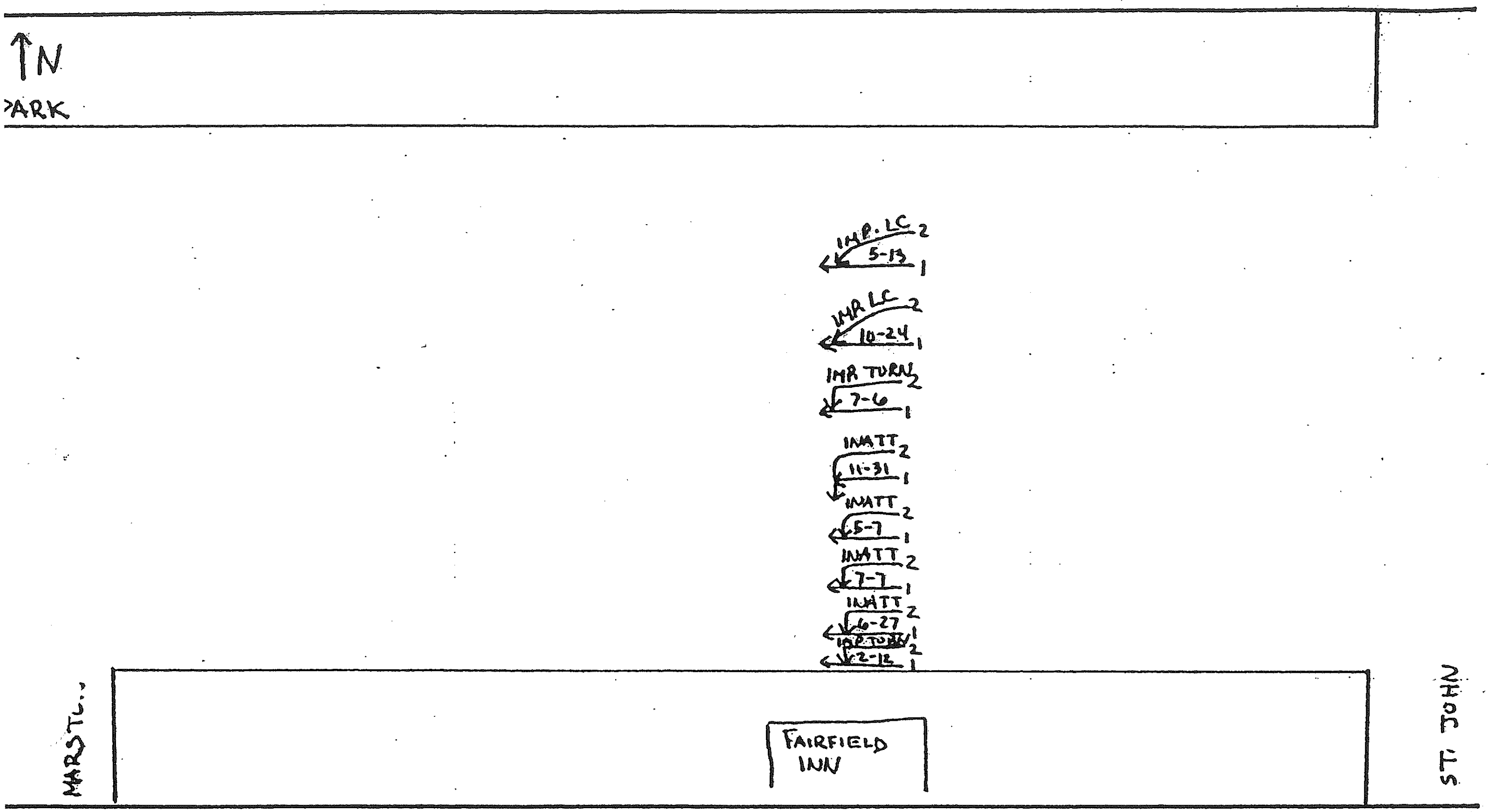
COLLISION DIAGRAM

SHEET 1 OF 1

OCATION PARK AVENUE FROM ST. JOHN TO MARSTON STREET

PORTLAND NODE NO(S) 07187 – 07188

EARS REVIEWED 2000 – 2002 DATE PREPARED 8/14/03



CRITICAL RATE FACTOR 1.13 EQUIV. PROP. DAMAGE ACC/YEAR 9 ACCIDENTS ACC/MEV

LIGHT

1. DAWN (MORNING) 2. DAYLIGHT 3. DUSK (EVENING)
4. DARK (ST. LIGHTS ON) 5. DARK (NO ST. LIGHTS) 6. DARK (ST. LIGHTS OFF)
7. OTHER

ROAD SURFACE

1. DRY 2. WET 3. SNOW/SLUSH-SANDED
4. ICE/PACKED SNOW-SANDED 5. MUDDY 6. DEBRIS
7. OILY 8. SNOW/SLUSH-NOT SANDED 9. ICE/PKD. SNOW-NOT SANDED
10. OTHER

APPARENT CONTRIBUTING FACTORS - HUMAN

1. NO IMPROPER ACTION 2. FAIL TO YLD. RIGHT OF WAY 3. ILLEGAL UNSAFE SPEED
4. FOLLOW TOO CLOSE 5. DISREGARD TRAFFIC CONTROL DEVICE
6. DRIVING LEFT OF CENTER - NO PASSING 7. IMPROPER PASS-OVERTAKING
8. IMP. UNSAFE LANE CHANGE 9. IMP. PARKING START/STOP 10. IMPROPER TURN
11. UNSAFE BACKING 12. NO SIGNAL OR IMP. SIGNAL 13. IMPEDING TRAFFIC
14. DRIVER INATTENTION - DISTRACTION 15. DRIVER INEXPERIENCE
16. PEDEST. VIOLATION ERROR 17. PHYSICAL IMPAIRMENT 18. VISION OBSCURED - WINDSHIELD GLASS 19. VISION OBSCURED - SUN/HEADLIGHTS
20. OTHER VISION OBSCUREMENT 30. OTHER HUMAN VIOLATION FACTOR
31. HIT AND RUN 51. UNKNOWN

- VEHICULAR

41. DEFECTIVE BRAKES 42. DEFECTIVE TIRE/FAILURE 43. DEFECTIVE LIGHTS
44. DEFECTIVE SUSPENSION OR FACTOR 45. DEFECTIVE STEERING 50. OTHER VEHICLE DEFECT
51. UNKNOWN

SYMBOLS

ANGLE PEDESTRIAN FATAL ACCIDENT ●
BACKING REAR END
FIXED OBJECT SIDE SWIPE VEHICLE (MOVING)
HEAD ON TURNING MOVE BICYCLE B
OVERTURN CHANGE LANE ANIMAL A
PARKED VEHICLE OUT OF CONTROL SLED S

WEATHER

C = CLEAR F = FOG R = RAIN
SL = SLEET S = SNOW CL = CLOUDY
XW = CROSS WINDS

INJURIES

K = FATAL B = NON-INCAPACITATING
A = INCAPACITATING C = POSSIBLE INJURY

REPORT NO.	DATE	TIME	INJURIES K	A	B	C	LIGHT	ROAD SURFACE	ACF	OTHER
022493	10-24-02	17:28	—	—	1	—	DUSK-3	DRY-1	8	
016235	7-6-02	18:38	—	—	1	—	DUSK-3	DRY-1	10	
^ 066	11-31-02	15:40	—	—	—	1	DAY-2	ICE-9	14	
693	5-13-01	11:20	—	—	—	—	DAY-2	DRY-1	8	
015162	5-7-01	13:17	—	—	—	—	DAY-2	DRY-1	14	
022139	7-7-01	20:54	—	—	—	—	DARK-4	DRY-1	14	
00.19309	6-27-00	14:19	—	—	—	—	DAY-2	DRY-1	14	

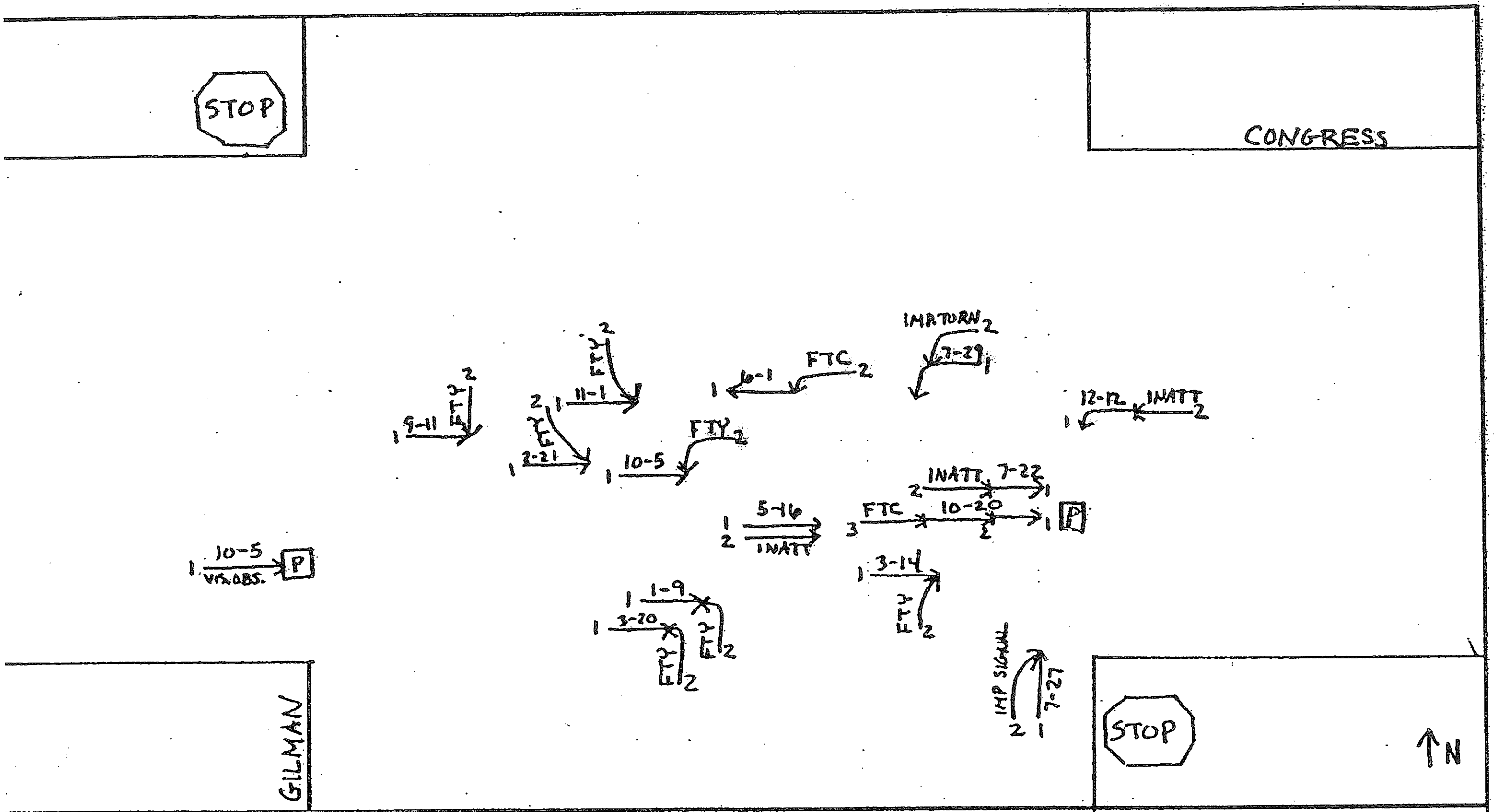
COLLISION DIAGRAM

SHEET 1 OF 2

OCATION Congress Street At Gilman Street

Portland NODE NO(S) 08991

EARS REVIEWED 2000-2002 DATE PREPARED 8/14/03



CRITICAL RATE FACTOR 1.49 EQUIV. PROP. DAMAGE ACC/YEAR 15 ACC ACC/MEV

LIGHT

1. DAWN (MORNING) 2. DAYLIGHT 3. DUSK (EVENING)
4. DARK (ST. LIGHTS ON) 5. DARK (NO ST. LIGHTS) 6. DARK (ST. LIGHTS OFF)
7. OTHER

ROAD SURFACE

1. DRY 2. WET 3. SNOW/SLUSH-SANDED
4. ICE/PACKED SNOW-SANDED 5. MUDDY 6. DEBRIS
7. OILY 8. SNOW/SLUSH-NOT SANDED 9. ICE/PKD. SNOW-NOT SANDED
10. OTHER

APPARENT CONTRIBUTING FACTORS - HUMAN

1. NO IMPROPER ACTION 2. FAIL TO YLD. RIGHT OF WAY 3. ILLEGAL UNSAFE SPEED
4. FOLLOW TOO CLOSE 5. DISREGARD TRAFFIC CONTROL DEVICE
6. DRIVING LEFT OF CENTER - NO PASSING 7. IMPROPER PASS-OVERTAKING
8. IMP. UNSAFE LANE CHANGE 9. IMP. PARKING START/STOP 10. IMPROPER TURN
11. UNSAFE BACKING 12. NO SIGNAL OR IMP. SIGNAL 13. IMPEDING TRAFFIC
14. DRIVER INATTENTION - DISTRACTION 15. DRIVER INEXPERIENCE
16. PEDEST. VIOLATION ERROR 17. PHYSICAL IMPAIRMENT 18. VISION OBSCURED - WINDSHIELD GLASS
19. VISION OBSCURED - SUN/HEADLIGHTS
20. OTHER VISION OBSCUREMENT 30. OTHER HUMAN VIOLATION FACTOR
31. HIT AND RUN 51. UNKNOWN

- VEHICULAR

41. DEFECTIVE BRAKES 42. DEFECTIVE TIRE/FAILURE 43. DEFECTIVE LIGHTS
44. DEFECTIVE SUSPENSION OR FACTOR 45. DEFECTIVE STEERING 50. OTHER VEHICLE DEFECT
51. UNKNOWN

SYMBOLS

ANGLE
PEDESTRIAN P
FATAL ACCIDENT ●
BACKING
REAR END
FIXED OBJECT
SIDE SWIPE
VEHICLE (MOVING)
HEAD ON
TURNING MOVE
BICYCLE B
OVERTURN
CHANGE LANE
ANIMAL A
PARKED VEHICLE
OUT OF CONTROL
SLED S

WEATHER

C = CLEAR
SL = SLEET
F = FOG
S = SNOW
R = RAIN
CL = CLOUDY
XW = CROSS WINDS

INJURIES

K = FATAL
A = INCAPACITATING
B = NON-INCAPACITATING
C = POSSIBLE INJURY

REPORT NO.	DATE	TIME	INJURIES K	A	B	C	LIGHT	ROAD SURFACE	ACF	OTHER
024667	12-12-02	7:38	—				DAY-2	SNOW-8	14	
017429	7-22-02	10:36	—				DAY-2	DRY-1	14	
0[illegible]2545	9-11-01	15:45	—				DAY-2	DRY-1	2	
[illegible]956	5-16-01	8:17	—				DAY-2	WET-2	14	
017468	6-1-01	17:30	—			1	DAY-2	DRY-1	4	
001104	1-9-01	17:35	—				DARK-4	WET-2	2,14	
030990	10-5-01	9:00	—	1			DAY-2	DRY-1	2	
034008	11-1-01	13:40	—			1	DAY-2	DRY-1	2	

COLLISION DIAGRAM

SHEET 2 OF 2

OCATION Congress Street at Gilman Street

Portland NODE NO(S) 08991

EARS REVIEWED 2000-2002 DATE PREPARED 8/14/03

REPORT NO.	DATE	TIME	INJURIES K	INJURIES A	INJURIES B	INJURIES C	LIGHT	ROAD SURFACE	ACF	OTHER
00.23105	7-27-00	13:04	—	—	—	—	DAY-2	WET-2	12,14	
00.11234	3-20-00	14:21	—	—	—	—	DAY-2	DRY-1	2	
00.09780	3-14-00	11:55	—	—	—	—	DAY-2	DRY-1	2	
00.07618	2-21-00	13:40	—	—	—	—	DAY-2	WET-2	2	
00.32131	10-20-00	10:10	—	—	—	—	DAY-2	DRY-1	4,14	
00.23261	7-29-00	14:12	—	—	1	—	DAY-2	DRY-1	10	
00.30677	10-5-00	19:44	—	—	1	—	DARK-4	WET-2	20	

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TINACC30                                     MAINE DEPARTMENT OF TRANSPORTATION
                                       TRAFFIC ENGINEERING, ACCIDENT RECORDS SECTION

                                                  ACCIDENT SUMMARY INPUT

TYPE OF STUDY: NODES AND LINKS       TYPE OF REQUEST: ACCIDENT I & II WITH LINK DETAIL
STUDY PERIOD: FROM MONTH 01 YEAR 2000 TO MONTH 12 YEAR 2002

 INPUT COMMENTS

   RTE 1 / RTE 25 AREA
   TOWN: PORTLAND


                                INPUT DATA

   ROUTE   COUNTY  FIRST   EXCLUDE  DISTANCE  SECOND   LAST  EXCLUDE  DISTANCE
                    NODE    FIRST              NODE    NODE   LAST

   60160    05     07184     0        0.00    03168   07241    0        0.00
   0022X           07189     0        0.00    07188   07187    0        0.00
   B001X           07187     1        0.00    07170   07170    0        0.00
   0001X           07170     1        0.00    09499   07251    0        0.00
   0025X           03065     0        0.00    03161   03043    1        0.00
   61239           03043     1        0.00    09491   07243    1        0.00
   60077           07243     1        0.00    08771   03037    0        0.00
   60785           03037     1        0.00    03164   03164    0        0.00
   60128           03036     0        0.00    03029   09532    0        0.00
   60071           09532     1        0.00    09531   09531    1        0.00
                   09531     1        0.00    09530   09530    0        0.00
   B001X           07180     0        0.00    07181   07182    1        0.00
                   07182     1        0.00    07187   07187    1        0.00
   60637           07187     1        0.00    03040   03041    0        0.00
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                                        MAINE DEPARTMENT OF TRANSPORTATION
TINACC30                            TRAFFIC ENGINEERING, ACCIDENT RECORDS SECTION

                                                ACCIDENT SUMMARY I

COUNTY LOW   HIGH    STREET NAME     U/R TOTAL  LINK    INJURY ACCIDENTS   PERCENT ANNUAL HM  ANNUAL M  ACCIDENT-RATES  CRITI   CRF
TOWN#  NODE  NODE    OR ROUTE #          ACCTS LENGTH   K   A   B   C  PD  INJURY  VEH-MILES  ENT-VEHS   LINK   NODE    RATE

05     07184 POR,CONGRESS,WESTFIELD  2     1            0   0   0   0   1    0.0               6.670          0.05    0.42   0.00
05     03168 POR,HEMLOCK,CONGRESS ST 2     0            0   0   0   0   0    0.0               7.444          0.00    0.41   0.00
05     02726 POR,CONGRESS ST,COUNTY  2     3            0   0   0   1   2   33.3               7.403          0.14    0.41   0.00
05     07183 POR,CONGRESS ST,RRING 8 2     0            0   0   0   0   0    0.0               6.970          0.00    0.41   0.00
05     07182 POR,CONGRESS,ST JOHN ST 9    26            0   1   5   5  15   42.3              13.509          0.64    1.00   0.00
05     07169 POR,VALLEY,CONGRESS ST. 9    24            0   0   0   6  18   25.0               7.850          1.02    1.10   0.00
05     08991 POR,GILMAN,CONGRESS ST. 2    15            0   1   2   2  10   33.3               8.681          0.58    0.39   1.49
05     07246 POR,CONGRESS,FOREST ST. 2     4            0   0   1   2   1   75.0               8.604          0.15    0.39   0.00
05     07245 POR,CONGRESS,WEYMOUTH S 2     8            0   0   0   4   4   50.0               6.305          0.42    0.42   1.00
05     07244 POR,CONGRESS,ELLSWORTH  2     1            0   0   0   0   1    0.0               7.476          0.04    0.40   0.00
05     07243 POR,CONGRESS,DEERING,BR 9    21            0   1   1   7  12   42.9              13.017          0.54    1.01   0.00
05     07242 POR,CONGRESS ST,MACMILL 2     1            0   0   0   1   0  100.0               8.839          0.04    0.39   0.00
05     07241 POR,CONGRESS,NEAL ST.   2     2            0   0   0   0   2    0.0               9.064          0.07    0.39   0.00
05     07189 POR,PARK AVE,ST.JAMES S 2     0            0   0   0   0   0    0.0               6.854          0.00    0.41   0.00
05     07188 POR,PARK AVE,MARSTON ST 2    10            0   0   2   2   6   40.0               6.586          0.51    0.42   1.21
05     07187 POR,RTE 22,PARK,ST JOHN 9    34            0   0   3   5  26   23.5              10.813          1.05    1.04   1.01
05     07170 POR, PARK AVE, VALLEY S 2     5            0   0   0   1   4   20.0               5.196          0.32    0.49   0.00
05     09499 POR,PARK AVE,GILMAN ST. 2     4            0   0   0   1   3   25.0               4.722          0.28    0.51   0.00
05     09498 POR,PARK AVE,FOREST ST. 2     3            0   0   0   1   2   33.3               5.576          0.18    0.49   0.00
05     09495 POR,PARK AVE,WEYMOUTH S 2     2            0   1   0   0   1   50.0               5.128          0.13    0.50   0.00
05     03043 POR,DEERING,PARK AVE.   9    16            0   0   0   2  14   12.5               8.635          0.62    1.08   0.00
05     09487 POR,PARK AVE,MELLEN ST. 9     7            0   0   0   1   6   14.3               6.350          0.37    1.14   0.00
05     07251 POR,STATE ST,PARK AVE.  9    24            0   1   5   7  11   54.2              10.428          0.77    1.04   0.00
05     03065 POR,DEERING,WASHBURN AV 2     6            0   0   2   1   3   50.0               3.707          0.54    0.48   1.13
05     03161 POR,DEERING AVE,D.O.UNN 2     0            0   0   0   0   0    0.0               3.677          0.00    0.48   0.00
05     03045 POR,DEERING AVE,OAKES,U 2     0            0   0   0   0   0    0.0               3.506          0.00    0.49   0.00
05     09491 POR,GRANT ST,DEERING AV 2     4            1   0   1   0   2   50.0               4.660          0.29    0.42   0.00
05     09493 POR,DEERING AVE,SHERMAN 2     1            0   0   0   0   1    0.0               5.251          0.06    0.41   0.00
05     09446 POR,DEERING,CUMBERLAND  2     7            0   0   0   0   7    0.0               5.890          0.40    0.39   1.03
05     08771 POR,BRAMHALL RD,BRAMHAL 2     1            0   0   0   1   0  100.0               3.413          0.10    0.45   0.00
05     03016 POR,BRAMHALL,VAUGHN ST. 2     1            0   0   0   1   0  100.0               4.444          0.08    0.42   0.00
05     03033 POR,BRAMHALL,HILL ST.   2     0            0   0   0   0   0    0.0               3.111          0.00    0.46   0.00
05     09531 POR,BRACKETT,BRAMHALL S 2     1            0   0   0   0   1    0.0               4.167          0.08    0.43   0.00
05     03015 POR,BRAMHALL,BRACKETT,C 2     0            0   0   0   0   0    0.0               2.639          0.00    0.46   0.00
05     03037 POR,WESTERN PROM,BRAMHA 2     0            0   0   0   0   0    0.0               1.667          0.00    0.52   0.00
05     03164 POR,WEST ST,WESTERN PRO 2     2            0   0   0   0   2    0.0               1.820          0.37    0.51   0.00
05     03036 POR,CHARLES,CRESCENT ST 2     0            0   0   0   0   0    0.0               0.473          0.00    0.67   0.00
05     03029 POR,ELLSWORTH,CHARLES S 2     1            0   0   0   0   1    0.0               0.723          0.46    0.63   0.00
05     09532 POR,CHARLES,BRACKETT ST 2     1            0   0   0   0   1    0.0               0.612          0.54    0.65   0.00
05     09530 POR,BRACKETT,VAUGHN ST. 2     5            0   0   0   2   3   40.0               5.478          0.30    0.40   0.00
05     07180 POR,ST JOHN ST,C ST     2     3            0   0   1   1   1   66.7               5.255          0.19    0.44   0.00
05     07181 POR,ST JOHN ST,A ST     2    10            0   0   2   1   7   30.0               6.046          0.55    0.43   1.28
05     03040 POR,ST JOHN ST,WASHBURN 2     3            0   0   0   2   1   66.7               4.107          0.24    0.43   0.00
05     03041 POR,ST JOHN,GRANITE ST  2     0            0   0   0   0   0    0.0               4.598          0.00    0.42   0.00

             NODE SUBTOTALS-             257            1   5  25  57 169   34.2             257.364          0.33    0.37   0.00
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TINACC30

MAINE DEPARTMENT OF TRANSPORTATION
TRAFFIC ENGINEERING, ACCIDENT RECORDS SECTION

ACCIDENT SUMMARY I

COUNTY TOWN#	LOW NODE	HIGH NODE	STREET NAME OR ROUTE #	U/R	TOTAL ACCTS	LINK LENGTH	INJURY ACCIDENTS					PERCENT INJURY	ANNUAL HM VEH-MILES	ANNUAL M ENT-VEHS	ACCIDENT-RATES		CRITI RATE	CRF
							K	A	B	C	PD				LINK	NODE		
05170	03168	07184	CONGRESS ST	2	0	0.01	0	0	0	0	0	0.0	0.00074		0.00		701.60	0.00
	02726	03168		2	1	0.04	0	0	0	0	1	0.0	0.00296		112.61		499.30	0.00
	02726	07183		2	1	0.01	0	0	0	0	1	0.0	0.00074		450.45		701.60	0.00
	07182	07183		2	4	0.07	0	0	0	0	4	0.0	0.00459		290.49		446.19	0.00
	07169	07182		2	5	0.06	0	0	1	0	4	20.0	0.00412		404.53		458.59	0.00
	07169	08991		2	2	0.02	0	0	0	0	2	0.0	0.00138		483.09		607.29	0.00
	07246	08991		2	3	0.06	0	0	2	0	1	66.7	0.00540		185.19		428.37	0.00
	07245	07246		2	3	0.10	0	0	0	1	2	33.3	0.00654		152.91		408.65	0.00
	07244	07245		2	5	0.09	0	0	1	1	3	40.0	0.00516		323.00		433.25	0.00
	07243	07244		2	5	0.06	0	1	0	2	2	60.0	0.00533		312.70		429.76	0.00
	07242	07243		2	6	0.04	0	0	0	1	5	16.7	0.00354		564.97		476.76	1.19
	07241	07242		2	2	0.05	0	0	0	0	2	0.0	0.00440		151.52		450.99	0.00
	07188	07189	PARK AVE	2	3	0.02	0	0	2	0	1	66.7	0.00140		714.29		605.11	1.18
	07187	07188		2	9	0.11	0	0	2	1	6	33.3	0.00649		462.25		409.41	1.13
	07170	07187		2	1	0.04	0	0	0	0	1	0.0	0.00208		160.26		547.10	0.00
	07170	09499		2	0	0.02	0	0	0	0	0	0.0	0.00090		0.00		883.05	0.00
	09498	09499		2	5	0.04	0	0	0	0	5	0.0	0.00184		905.80		735.74	1.23
	09495	09498		2	4	0.09	0	0	1	2	1	75.0	0.00415		321.29		598.10	0.00
	03043	09495		2	8	0.15	0	0	1	2	5	37.5	0.00702		379.87		527.90	0.00
	03043	09487		2	6	0.14	0	0	0	1	5	16.7	0.00741		269.91		396.52	0.00
	07251	09487		2	5	0.12	0	0	0	1	4	20.0	0.00673		247.65		405.82	0.00
	03065	03161	DEERING AVE	2	2	0.12	0	0	0	0	2	0.0	0.00449		148.48		448.68	0.00
	03045	03161		2	1	0.14	0	0	0	0	1	0.0	0.00475		70.18		442.35	0.00
	03043	03045		2	3	0.04	0	0	1	0	2	33.3	0.00136		735.29		609.49	1.21
	03043	09491		2	2	0.06	0	1	0	0	1	50.0	0.00234		284.90		554.16	0.00
	09491	09493		2	3	0.04	0	0	0	1	2	33.3	0.00199		502.51		577.90	0.00
	09446	09493		2	0	0.05	0	0	0	0	0	0.0	0.00249		0.00		545.30	0.00
	07243	09446		2	1	0.03	0	0	0	0	1	0.0	0.00149		223.71		622.37	0.00
	07243	08771	BRAMHALL ST	2	0	0.01	0	0	0	0	0	0.0	0.00033		0.00		780.64	0.00
	03016	08771		2	0	0.02	0	0	0	0	0	0.0	0.00067		0.00		707.76	0.00
	03016	03033		2	0	0.03	0	0	0	0	0	0.0	0.00092		0.00		661.77	0.00
	03033	09531		2	0	0.05	0	0	0	0	0	0.0	0.00139		0.00		599.76	0.00
	03015	09531	BRACKETT ST	2	2	0.02	0	0	0	1	1	50.0	0.00039		1709.40		1410.73	1.21
	03015	03037	BRAMHALL ST	2	3	0.11	0	0	1	0	2	33.3	0.00183		546.45		960.21	0.00
	03037	03164	WESTERN PROM	2	0	0.05	0	0	0	0	0	0.0	0.00083		0.00		1177.61	0.00
	03029	03036	CHARLES ST	2	1	0.06	0	1	0	0	0	100.0	0.00033		1010.10		1460.35	0.00
	03029	09532		2	0	0.03	0	0	0	0	0	0.0	0.00017		0.00		1609.82	0.00
	09531	09532	BRACKETT ST	2	0	0.04	0	0	0	0	0	0.0	0.00022		0.00		1564.90	0.00
	09530	09531		2	0	0.06	0	0	0	0	0	0.0	0.00183		0.00		559.49	0.00
	07180	07181	ST JOHN ST	2	6	0.10	0	0	0	0	6	0.0	0.00519		385.36		432.62	0.00
	07181	07182		2	16	0.07	0	0	1	1	14	12.5	0.00468		1139.60		444.01	2.57
	07182	07187		2	38	0.17	0	0	2	8	28	26.3	0.01174		1078.93		356.60	3.03
	03040	07187		2	2	0.04	0	0	0	0	2	0.0	0.00144		462.96		627.76	0.00
	03040	03041		2	3	0.11	0	0	0	0	3	0.0	0.00504		198.41		455.35	0.00
			LINK SUBTOTALS-		161	2.79	0	3	15	23	120	25.5	0.13883		386.56		253.66	1.52

```
TINACC30                  MAINE DEPARTMENT OF TRANSPORTATION
                    TRAFFIC ENGINEERING, ACCIDENT RECORDS SECTION

                                ACCIDENT SUMMARY I

             GRAND TOTALS-     418    2.79    1   8  40  80  289  30.9     0.13883  257.364  1003.62      431.49   2.33
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TINACC30

MAINE DEPARTMENT OF TRANSPORTATION
TRAFFIC ENGINEERING, ACCIDENT RECORDS SECTION

ACCIDENT SUMMARY II - CHARACTERISTICS

H O U R O F D A Y

	---A M---												---P M---														
DAY OF WEEK	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	UNKNOWN	TOTAL	
SUNDAY	4	1	0	1	0	0	0	3	1	1	2	4	4	5	2	2	3	2	1	3	1	0	0	1	0	41	S
MONDAY	0	0	0	0	0	0	2	4	1	3	3	1	5	5	8	10	9	6	0	2	2	3	1	1	0	66	M
TUESDAY	1	0	0	0	0	1	0	3	2	4	3	3	5	8	8	9	5	7	1	3	0	0	3	0	0	66	T
WEDNESDAY	1	0	1	0	0	0	0	2	4	1	5	3	5	2	9	6	9	8	2	3	1	1	1	0	0	64	W
THURSDAY	0	0	0	1	0	0	0	2	4	0	3	5	5	7	4	6	6	6	4	4	4	0	1	2	0	64	T
FRIDAY	1	1	0	0	0	0	0	2	3	5	2	5	7	7	1	12	5	8	5	3	2	1	2	0	0	72	F
SATURDAY	0	1	0	0	0	0	0	3	1	2	3	5	3	2	7	4	1	0	2	1	6	1	2	1	0	45	S
UNKNOWN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	U
TOTAL	7	3	1	2	0	1	2	19	16	16	21	26	34	36	39	49	38	37	15	19	16	6	10	5	0	418	T

		YEAR		
	TOTAL	2000	2001	2002
JANUARY	48	17	15	16
FEBRUARY	35	12	14	9
MARCH	40	24	6	10
APRIL	27	11	8	8
MAY	25	6	13	6
JUNE	36	13	12	11
JULY	39	15	12	12
AUGUST	26	7	9	10
SEPTEMBER	25	9	8	8
OCTOBER	49	18	16	15
NOVEMBER	29	15	13	1
DECEMBER	39	13	12	14
UNKNOWN	0	0	0	0
TOTAL	418	160	138	120

TYPE OF UNIT

01-2 DOOR	134	10-BOBTAIL	1
02-4 DOOR	389	20-2ADT	10
03-CONVERTBLE	1	30-3ASU	5
04-STAT WGN	53	40-4ASU	0
05-VAN/CAMPER	72	21-2ASA	0
06-PICKUP TRK	88	22-2ATA	1
12-SCHOOL BUS	2	31-3ASA	0
13-MOTOR HOME	0	32-3ATA	1
14-MOTORCYCLE	3	33-3ATR	0
15-MOPED	0	42-4ATA	0
16-MOTOR BIKE	0	25-2AT1A2ATR	0
17-BICYCLE	3	35-3AT1A2ATR	0
18-SNOWMOBILE	0	36-3AT2A2ATR	0
19-PEDESTRIAN	19	50-OTHER	0
23-ATV	0	81-2AX CM BUS	7
07-SUV	45	82-3AX CM BUS	3
99-UNK/OTH	0	98-FARM/TRAC	1
TOTAL	838		

TINACC30

MAINE DEPARTMENT OF TRANSPORTATION
TRAFFIC ENGINEERING, ACCIDENT RECORDS SECTION

ACCIDENT SUMMARY II - CHARACTERISTICS

TYPE OF LOCATION

ACCIDENT TYPE	ST ROAD	CURV ROAD	**AT INTERSECTION** 3-LEG	4-LEG	5-LEG	DRIVE WAYS	BRIDGE	INTER CHANGE	UN KNOWN	TOTAL
OBJECT IN ROAD	0	0	0	0	0	0	1	0	0	1
REAR END/SIDESWIPE	84	2	38	83	0	18	0	0	1	226
HEAD-ON/SIDESWIPE	4	2	4	2	0	0	0	0	0	12
INTERSECTION MOVEMENT	0	0	21	77	0	46	0	0	0	144
PEDESTRIANS	4	0	5	8	0	1	0	0	0	18
TRAIN	0	0	0	0	0	0	0	0	0	0
RAN OFF ROAD	4	0	3	2	0	0	0	0	1	10
ANIMAL	0	0	0	0	0	0	0	0	0	0
DEER	0	0	0	0	0	0	0	0	0	0
MOOSE	0	0	0	0	0	0	0	0	0	0
BEAR	0	0	0	0	0	0	0	0	0	0
SLED/BIKE	0	0	1	0	0	1	0	0	0	2
OTHER	2	0	2	1	0	0	0	0	0	5
NON COLLISION	0	0	0	0	0	0	0	0	0	0
UNKNOWN	0	0	0	0	0	0	0	0	0	0
TOTAL	98	4	74	173	0	66	1	0	2	418

INJURY DATA

SEV CODE	INJURY ACCIDENTS	NUMBER OF INJURIES
K	1	1
A	8	10
B	40	46
C	80	112
PD	289	
TOTAL	418	169

FIXED OBJECT STRUCK

CONSTRUCTION BARRICADES	2
TRAFFIC SIGNAL	0
R/R CROSSING	0
LIGHT POLE	0
UTILITY POLE	0
SIGN POST	2
MAIL BOXES	0
OTHER POLES/POSTS	0
FIRE PLUG/PARK METER	0
TREE/SHRUBBERY	1
CRASH CUSHION	0
MEDIAN SAFETY BARRIER	0
BRIDGE PIERS	2
OTHER GUARDRAILS	0
FENCING NOT BARRIER	0
CULVERT HEADWALL	0
EMBANKMENT/DITCH	1
BUILDING WALL	0
ROCK OUTCROPPING/LEDGE	0
OTHER	5
UNKNOWN	0
TOTAL	13

TRAFFIC CONTROL DEVICES

TRAFFIC SIG STOP/GO	161
TRAFFIC SIG FLASHING	8
OVERHEAD FLASHERS	1
ALL WAY STOP	6
STOP SIGN/OTHER	47
YIELD SIGN	4
CURVE SIGN	1
OFFICER /SCHOOL PAT	1
SCHOOL BUS STOP ARM	0
SCHOOL ZONE SIGN	1
R/R CROSSING DEVICE	0
NO PASSING ZONE	1
NONE	179
OTHER	7
UNKNOWN	1
TOTAL	418

ROAD CHARACTER

LEVEL STRAIGHT	272
LEVEL CURVED	13
ON GRADE STRAIGHT	101
ON GRADE CURVED	10
TOP OF HILL STRAIGHT	12
TOP OF HILL CURVED	1
BOTTOM OF HILL STRAIGHT	7
BOTTOM OF HILL CURVED	2
UNKNOWN	0
TOTAL	418

TINACC30

MAINE DEPARTMENT OF TRANSPORTATION
TRAFFIC ENGINEERING, ACCIDENT RECORDS SECTION

ACCIDENT SUMMARY II - CHARACTERISTICS

APPARENT CONTRIBUTING FACTOR	DR 1	DR 2	DR 3	DR 4	DR 5	OTHER	TOTAL
HUMAN FACTORS							
NO INPROPER DRIVING	259	115	12	1	0	0	387
FAIL TO YIELD R-WAY	31	56	0	0	0	0	87
ILLEGAL UNSAFE SPEED	2	3	0	0	0	0	5
FOLLOW TOO CLOSE	4	17	2	0	0	0	23
DISREGARD TRAF CONTROL	4	22	1	0	0	0	27
DRIVING LEFT OF CENTER	1	1	0	0	0	0	2
IMPROPER PASSING	0	3	0	0	0	0	3
IMPROPER LANE CHANGE	7	9	1	0	0	0	17
IMPROPER START/STOP	3	10	1	0	0	0	14
IMPROPER TURN	8	14	0	0	0	0	22
UNSAFE BACKING	2	4	0	0	0	0	6
NO PROPER SIGNAL	2	1	0	0	0	0	3
IMPEDING TRAFFIC	0	1	0	0	0	0	1
DRIVER INATTENTION	45	77	9	1	0	0	132
DRIVER INEXPERIENCE	5	2	0	0	0	0	7
PEDESTRIAN VIOLATION	0	15	0	0	0	0	15
PHYSICAL IMPAIRMENT	3	2	0	0	0	0	5
VISION OBSCURED GLASS	1	0	0	0	0	0	1
VISION OBSCURED LIGHT	2	3	0	0	0	0	5
VISION OBSCURED OTHER	10	12	0	0	0	0	22
OTHER HUMAN FACTOR	12	13	3	0	0	0	28
HIT & RUN	2	9	1	0	0	0	12
VEHICULAR FACTORS							
DEFECTIVE BRAKES	0	0	0	0	0	0	0
DEFECTIVE TIRE	0	0	0	0	0	0	0
DEFECTIVE LIGHTS	0	0	0	0	0	0	0
DEFECTIVE SUSPENSION	0	0	0	0	0	0	0
DEFECTIVE STEERING	0	0	0	0	0	0	0
OTHER VEHICLE DEFECT	2	1	0	0	0	0	3
UNKNOWN	7	4	0	0	0	0	11
TOTAL	412	394	30	2	0	0	838

APPARENT PHYSICAL CONDITION	DR 1	DR 2	DR 3	DR 4	DR 5	OTHER	TOTAL
NORMAL	402	373	26	2	0	0	803
UNDER THE INFLUENCE	1	12	0	0	0	0	13
DRINKING	1	3	0	0	0	0	4
USING DRUGS	0	1	1	0	0	0	2
ASLEEP	1	0	0	0	0	0	1
FATIGUED	1	0	0	0	0	0	1
ILL	0	0	0	0	0	0	0
HANDICAPPED	0	1	0	0	0	0	1
OTHER/UNKNOWN	6	4	3	0	0	0	13
TOTAL	412	394	30	2	0	0	838

	TYPE OF UNIT					
AGE	DRIVER	BIKE	SNOW SLED	PED	ATV	TOTAL
9-UNDER	0	0	0	0	0	0
10-14	0	0	0	3	0	3
15-19	64	0	0	2	0	66
20-24	126	1	0	1	0	128
25-29	93	0	0	1	0	94
30-39	161	2	0	0	0	163
40-49	159	0	0	7	0	166
50-59	99	0	0	2	0	101
60-69	44	0	0	3	0	47
70-79	36	0	0	0	0	36
80-OVER	12	0	0	0	0	12
UNKNOWN	22	0	0	0	0	22
TOTAL	816	3	0	19	0	838

TINACC30

MAINE DEPARTMENT OF TRANSPORTATION
TRAFFIC ENGINEERING, ACCIDENT RECORDS SECTION

ACCIDENT SUMMARY II - CHARACTERISTICS

ROAD SURFACE

WEATHER	LIGHT CONDITION	DRY	WET	SNOW SAND	ICE SAND	MUD	DEBRIS	OIL	SNOW	ICE	OTHER	TOTAL
CLEAR	DAWN	3	0	0	0	0	0	0	0	0	0	3
	DAYLIGHT	183	13	3	2	0	0	0	0	1	0	202
(267)	DUSK	16	2	1	1	0	0	0	0	0	0	20
	DARK-LIGHTS	35	4	1	1	0	0	0	0	0	0	41
	DARK NO LIGHTS	1	0	0	0	0	0	0	0	0	0	1
	DARK LIGHTS OFF	0	0	0	0	0	0	0	0	0	0	0
	OTHER	0	0	0	0	0	0	0	0	0	0	0
	UNKNOWN	0	0	0	0	0	0	0	0	0	0	0
RAIN	DAWN	0	0	0	0	0	0	0	0	0	0	0
	DAYLIGHT	0	25	0	0	0	0	0	0	1	0	26
(45)	DUSK	0	1	0	0	0	0	0	0	0	0	1
	DARK-LIGHTS	1	15	0	0	0	0	0	0	0	0	16
	DARK NO LIGHTS	0	1	0	0	0	0	0	0	0	0	1
	DARK LIGHTS OFF	0	0	0	0	0	0	0	0	0	0	0
	OTHER	1	0	0	0	0	0	0	0	0	0	1
	UNKNOWN	0	0	0	0	0	0	0	0	0	0	0
SNOW	DAWN	0	0	0	0	0	0	0	0	0	0	0
	DAYLIGHT	0	4	6	0	0	0	0	5	1	0	16
(30)	DUSK	0	0	0	0	0	0	0	1	1	0	2
	DARK-LIGHTS	0	1	1	1	0	0	0	7	1	0	11
	DARK NO LIGHTS	0	0	0	0	0	0	0	1	0	0	1
	DARK LIGHTS OFF	0	0	0	0	0	0	0	0	0	0	0
	OTHER	0	0	0	0	0	0	0	0	0	0	0
	UNKNOWN	0	0	0	0	0	0	0	0	0	0	0
SLEET/HAIL	DAWN	0	0	0	0	0	0	0	0	0	0	0
	DAYLIGHT	0	0	0	0	0	0	0	0	1	0	1
(4)	DUSK	0	1	1	0	0	0	0	0	0	0	2
	DARK-LIGHTS	0	1	0	0	0	0	0	0	0	0	1
	DARK NO LIGHTS	0	0	0	0	0	0	0	0	0	0	0
	DARK LIGHTS OFF	0	0	0	0	0	0	0	0	0	0	0
	OTHER	0	0	0	0	0	0	0	0	0	0	0
	UNKNOWN	0	0	0	0	0	0	0	0	0	0	0
FOG/SMOG	DAWN	0	0	0	0	0	0	0	0	0	0	0
	DAYLIGHT	0	1	0	0	0	0	0	0	0	0	1
(2)	DUSK	0	0	0	0	0	0	0	0	0	0	0
	DARK-LIGHTS	0	1	0	0	0	0	0	0	0	0	1
	DARK NO LIGHTS	0	0	0	0	0	0	0	0	0	0	0
	DARK LIGHTS OFF	0	0	0	0	0	0	0	0	0	0	0
	OTHER	0	0	0	0	0	0	0	0	0	0	0
	UNKNOWN	0	0	0	0	0	0	0	0	0	0	0

LIGHT	
DAWN	6
DAYLIGHT	297
DUSK	28
DARK-LIGHTS	81
DARK NO LIGHTS	3
DARK LIGHTS OFF	1
OTHER	2
UNKNOWN	0
TOTAL	418

TINACC30

MAINE DEPARTMENT OF TRANSPORTATION
TRAFFIC ENGINEERING, ACCIDENT RECORDS SECTION

ACCIDENT SUMMARY II - CHARACTERISTICS

WEATHER	LIGHT CONDITION	ROAD SURFACE										
		DRY	WET	SNOW SAND	ICE SAND	MUD	DEBRIS	OIL	SNOW	ICE	OTHER	TOTAL
CROSS WINDS	DAWN	0	0	0	0	0	0	0	0	0	0	0
	DAYLIGHT	0	0	0	0	0	0	0	0	0	0	0
(0)	DUSK	0	0	0	0	0	0	0	0	0	0	0
	DARK-LIGHTS	0	0	0	0	0	0	0	0	0	0	0
	DARK NO LIGHTS	0	0	0	0	0	0	0	0	0	0	0
	DARK LIGHTS OFF	0	0	0	0	0	0	0	0	0	0	0
	OTHER	0	0	0	0	0	0	0	0	0	0	0
	UNKNOWN	0	0	0	0	0	0	0	0	0	0	0
SAND/DUST	DAWN	0	0	0	0	0	0	0	0	0	0	0
	DAYLIGHT	0	0	0	0	0	0	0	0	0	0	0
(0)	DUSK	0	0	0	0	0	0	0	0	0	0	0
	DARK-LIGHTS	0	0	0	0	0	0	0	0	0	0	0
	DARK NO LIGHTS	0	0	0	0	0	0	0	0	0	0	0
	DARK LIGHTS OFF	0	0	0	0	0	0	0	0	0	0	0
	OTHER	0	0	0	0	0	0	0	0	0	0	0
	UNKNOWN	0	0	0	0	0	0	0	0	0	0	0
CLOUDY	DAWN	2	1	0	0	0	0	0	0	0	0	3
	DAYLIGHT	40	10	0	0	0	0	0	0	0	0	50
(68)	DUSK	3	0	0	0	0	0	0	0	0	0	3
	DARK-LIGHTS	6	5	0	0	0	0	0	0	0	0	11
	DARK NO LIGHTS	0	0	0	0	0	0	0	0	0	0	0
	DARK LIGHTS OFF	0	0	0	0	0	0	0	0	0	0	0
	OTHER	0	1	0	0	0	0	0	0	0	0	1
	UNKNOWN	0	0	0	0	0	0	0	0	0	0	0
OTHER	DAWN	0	0	0	0	0	0	0	0	0	0	0
	DAYLIGHT	0	0	0	0	0	0	0	0	0	1	1
(2)	DUSK	0	0	0	0	0	0	0	0	0	0	0
	DARK-LIGHTS	0	0	0	0	0	0	0	0	0	0	0
	DARK NO LIGHTS	0	0	0	0	0	0	0	0	0	0	0
	DARK LIGHTS OFF	0	1	0	0	0	0	0	0	0	0	1
	OTHER	0	0	0	0	0	0	0	0	0	0	0
	UNKNOWN	0	0	0	0	0	0	0	0	0	0	0
ROAD SURFACE TOTALS		291	88	13	5	0	0	0	14	6	1	418

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PAGE   1                                                                                    JUL 25,2003 AT 09:

                                       MAINE DEPARTMENT OF TRANSPORTATION
 TINACC30                            TRAFFIC ENGINEERING, ACCIDENT RECORDS SECTION

                                             ACCIDENT SUMMARY INPUT

 TYPE OF STUDY: NODES AND LINKS     TYPE OF REQUEST: ACCIDENT I & II WITH LINK DETAIL
 STUDY PERIOD: FROM MONTH 01 YEAR 2000 TO MONTH 12 YEAR 2002

  INPUT COMMENTS

    RTE 1 / RTE 25 AREA
    TOWN: PORTLAND


                               INPUT DATA

    ROUTE    COUNTY  FIRST   EXCLUDE  DISTANCE  SECOND   LAST  EXCLUDE  DISTANCE
                     NODE    FIRST              NODE     NODE   LAST

    60160     05     07184     0        0.00    03168   07241    0        0.00
    0022X            07189     0        0.00    07188   07187    0        0.00
    B001X            07187     1        0.00    07170   07170    0        0.00
    0001X            07170     1        0.00    09499   07251    0        0.00
    0025X            03065     0        0.00    03161   03043    1        0.00
    61239            03043     1        0.00    09491   07243    1        0.00
    60077            07243     1        0.00    08771   03037    0        0.00
    60785            03037     1        0.00    03164   03164    0        0.00
    60128            03036     0        0.00    03029   09532    0        0.00
    60071            09532     1        0.00    09531   09531    1        0.00
                     09531     1        0.00    09530   09530    0        0.00
    B001X            07180     0        0.00    07181   07182    1        0.00
                     07182     1        0.00    07187   07187    1        0.00
    60637            07187     1        0.00    03040   03041    0        0.00
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TINACC30

MAINE DEPARTMENT OF TRANSPORTATION
TRAFFIC ENGINEERING, ACCIDENT RECORDS SECTION

LINK DETAIL

TOWN#	STREET NAME OR ROUTE #	LOW NODE	HIGH NODE	DISTANCE	TOTAL ACCIDENTS	INJURY ACCIDENTS K	A	B	C	PD	ACCIDENT REPORT NUMBERS
05170	CONGRESS ST	03168	07184	0.0	0	0	0	0	0	0	
		02726	03168	0.1	1	0	0	0	0	1	200139633
		02726	07183	0.1	1	0	0	0	0	1	200130425
		07182	07183	0.1	4	0	0	0	0	4	200012896 200018244 200030454 200122888
		07169	07182	0.1	5	0	0	1	0	4	200013537 200031901 200209951 200209117 200217888
		07169	08991	0.1	2	0	0	0	0	2	200006326 200026647
		07246	08991	0.1	3	0	0	2	0	1	200032721 200121904 200204122
		07245	07246	0.1	3	0	0	0	1	2	200004462 200022827 200127069
		07244	07245	0.1	5	0	0	1	1	3	200001554 200009009 200035471 200131233 200138179
		07243	07244	0.1	5	0	1	0	2	2	200004723 200040016 200040904 200210251 200222044
		07242	07243	0.1	6	0	0	0	1	5	200007733 200033466 200030551 200101233 200131985 200219704
		07241	07242	0.1	2	0	0	0	0	2	200218482 200221116
	PARK AVE	07188	07189	0.1	3	0	0	2	0	1	200127799 200130514 200201206
		07187	07188	0.1	9	0	0	2	1	6	200006303 200019309 200115162 200115693 200115768 200122139 200206066 200216235 200222493
		07170	07187	0.1	1	0	0	0	0	1	200218309
		09498	09499	0.1	5	0	0	0	0	5	200030796 200041955 200105130 200137292 200211154
		09495	09498	0.1	4	0	0	1	2	1	200037299 200038142 200130308 200225350
		03043	09495	0.1	8	0	0	1	2	5	200030556 200034911 200039998 200136528 200211586 200214661 200215491 200225852
		03043	09487	0.1	6	0	0	0	1	5	200011017 200006312 200029304 200131090 200217494 200225512
		07251	09487	0.1	5	0	0	0	1	4	200019251 200034842 200203240 200217887 200222631
	DEERING AVE	03065	03161	0.1	2	0	0	0	0	2	200024016 200137321
		03045	03161	0.1	1	0	0	0	0	1	200009782
		03043	03045	0.1	3	0	0	1	0	2	200029854 200034509 200111953
		03043	09491	0.1	2	0	1	0	0	1	200209377 200219255
		09491	09493	0.1	3	0	0	0	1	2	200008411 200124502 200225714
	BRAMHALL ST	07243	09446	0.1	1	0	0	0	0	1	200009013
	BRACKETT ST	03015	09531	0.1	2	0	0	0	1	1	200129717 200202270
	WESTERN PROM	03015	03037	0.1	3	0	0	1	0	2	200006769 200221261 200222074
	BRACKETT ST	03029	03036	0.1	1	0	1	0	0	0	200116426
	ST JOHN ST	07180	07181	0.1	6	0	0	0	0	6	200003033 200026734 200120419 200134556 200200892 200225546
		07181	07182	0.1	16	0	0	1	1	14	200016848 200022247 200031179 200038362 200102764 200117882 200116054 200122637 200126210 200201316 200217788 200221457 200221678 200222823 200222494 200225019
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TINACC30                      MAINE DEPARTMENT OF TRANSPORTATION
                         TRAFFIC ENGINEERING, ACCIDENT RECORDS SECTION

                                        LINK DETAIL

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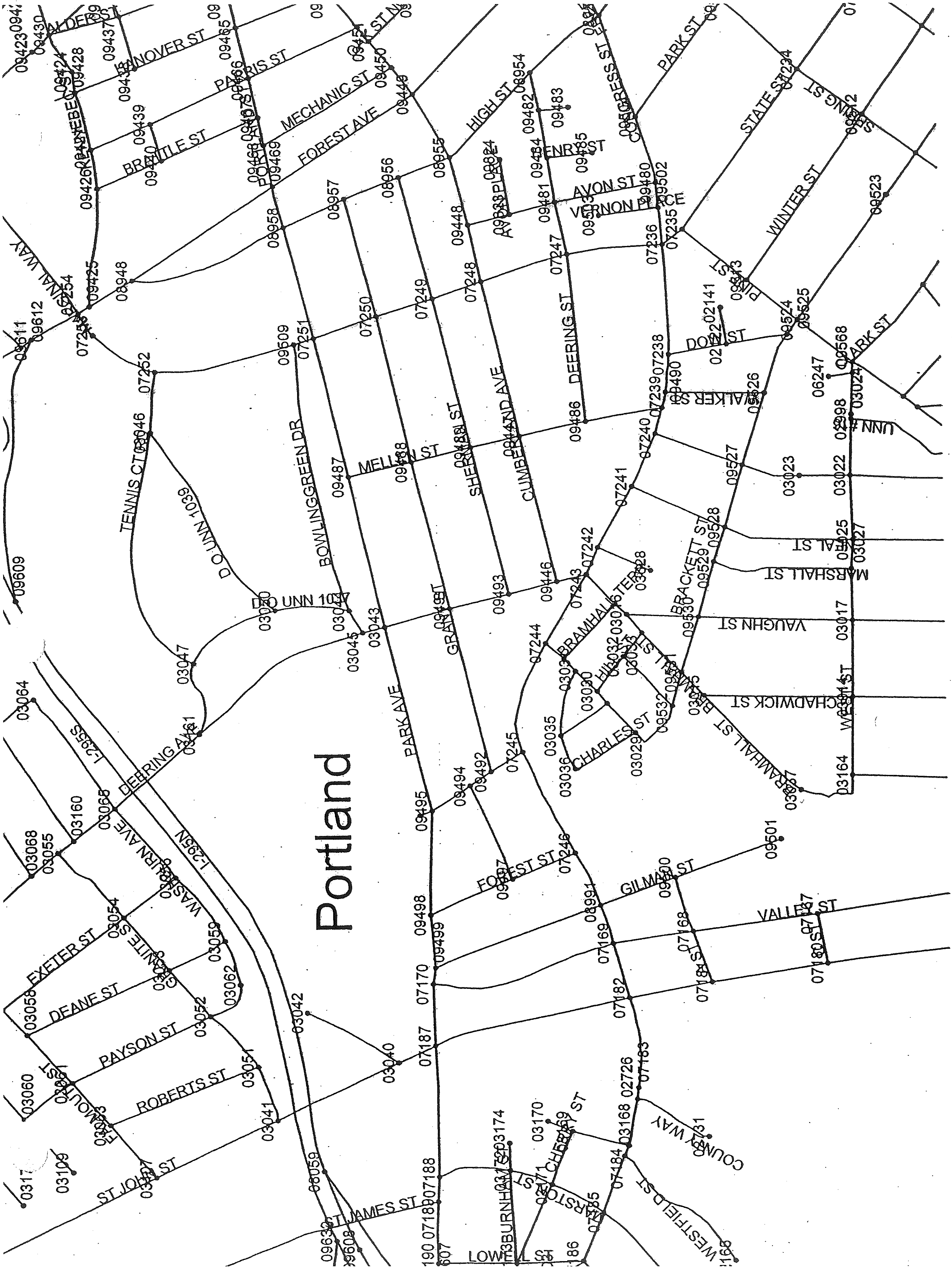

Portland
ALDER ST
HANOVER ST
PARIS ST
KENNEBEC ST
BRATTLE ST
PORTLAND ST
MECHANIC ST
FOREST AVE
HIGH ST
HENRY ST
AVON ST
AVON PL
VERNON PLACE
CONGRESS ST
PARK ST
STATE ST
SPRING ST
WINTER ST
PINE ST
DEERING ST
DOW ST
PARK ST
WALKER ST
UNN
CUMBERLAND AVE
SHERMAN ST
MELLEN ST
BOWLINGGREEN DR
TENNIS CT
D O UNN 1039
D O UNN 1037
GRANT ST
PARK AVE
BRACKETT ST
NEAL ST
MARSHALL ST
VAUGHN ST
BRAMHALL TERR
HILL ST
CHADWICK ST
WEST ST
CHARLES ST
BRAMHALL ST
DEERING AVE
I295S
I295N
WASHBURN AVE
FOREST ST
GILMAN ST
VALLEY ST
EXETER ST
DEANE ST
PAYSON ST
ROBERTS ST
FALMOUTH ST
GRANITE ST
ST JOHN ST
ST JAMES ST
COUNTY WAY
WESTFIELD ST
CHERRY ST
BURNHAM ST
LOWELL ST
CANAL WAY

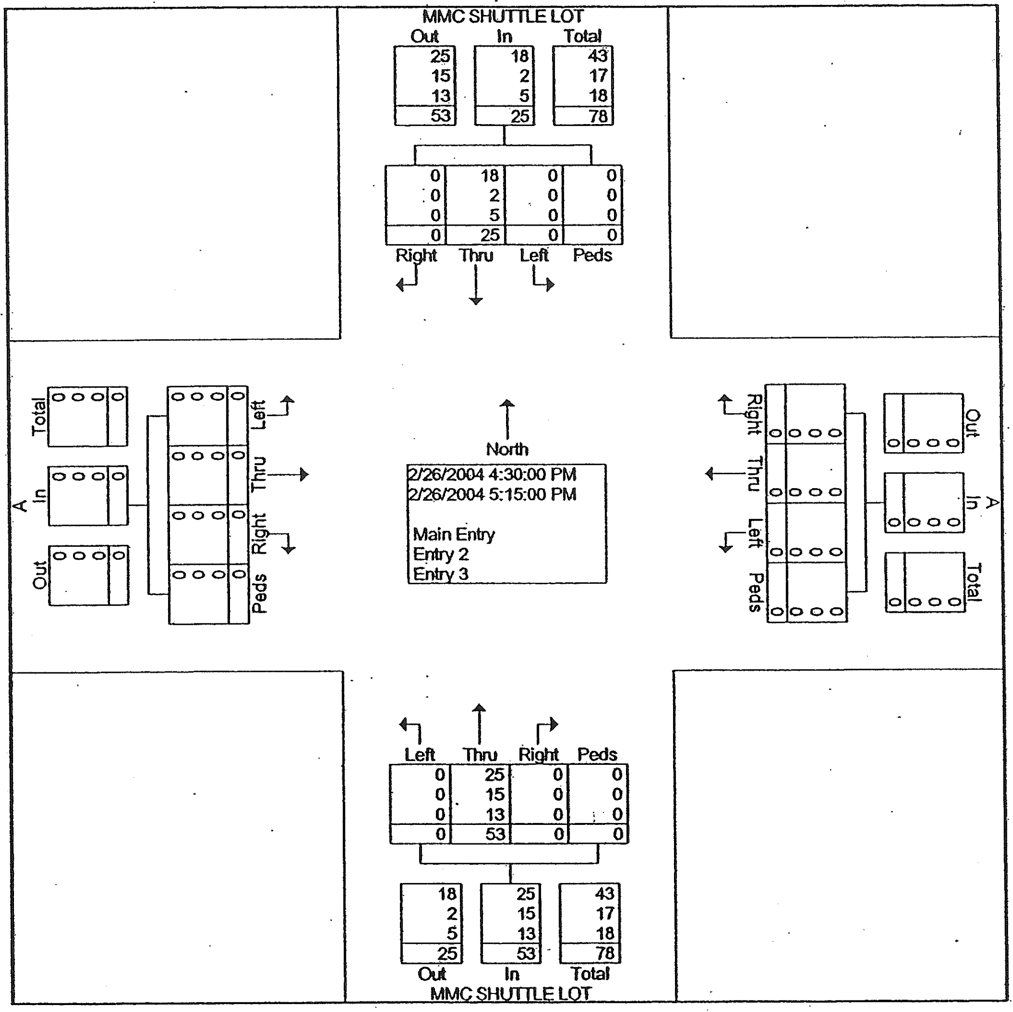
Gorrill-Palmer Consulting Engineers, Inc
15 Shaker Road
Gray, ME 04039
(207) 657-6910 FAX 657-6912

cation: Portland, Maine
unted by: E. Bartlett

File Name : ShuttleLotPM
Site Code : 00000317
Start Date : 02/26/2004
Page No : 1

Groups Printed- Main Entry - Entry 2 - Entry 3

	MMC SHUTTLE LOT From North					A From East					MMC SHUTTLE LOT From South					A From West					
art Time	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	Int. Total
Factor	1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0		
4:30 PM	0	4	0	0	4	0	0	0	0	0	0	17	0	0	17	0	0	0	0	0	21
4:45 PM	0	6	0	0	6	0	0	0	0	0	0	8	0	0	8	0	0	0	0	0	14
Total	0	10	0	0	10	0	0	0	0	0	0	25	0	0	25	0	0	0	0	0	35
5:00 PM	0	7	0	0	7	0	0	0	0	0	0	20	0	0	20	0	0	0	0	0	27
5:15 PM	0	8	0	0	8	0	0	0	0	0	0	8	0	0	8	0	0	0	0	0	16
Grand Total	0	25	0	0	25	0	0	0	0	0	0	53	0	0	53	0	0	0	0	0	78
pprch %	0.0	100.0	0.0	0.0		0.0	0.0	0.0	0.0		0.0	100.0	0.0	0.0		0.0	0.0	0.0	0.0		
Total %	0.0	32.1	0.0	0.0	32.1	0.0	0.0	0.0	0.0	0.0	0.0	67.9	0.0	0.0	67.9	0.0	0.0	0.0	0.0	0.0	



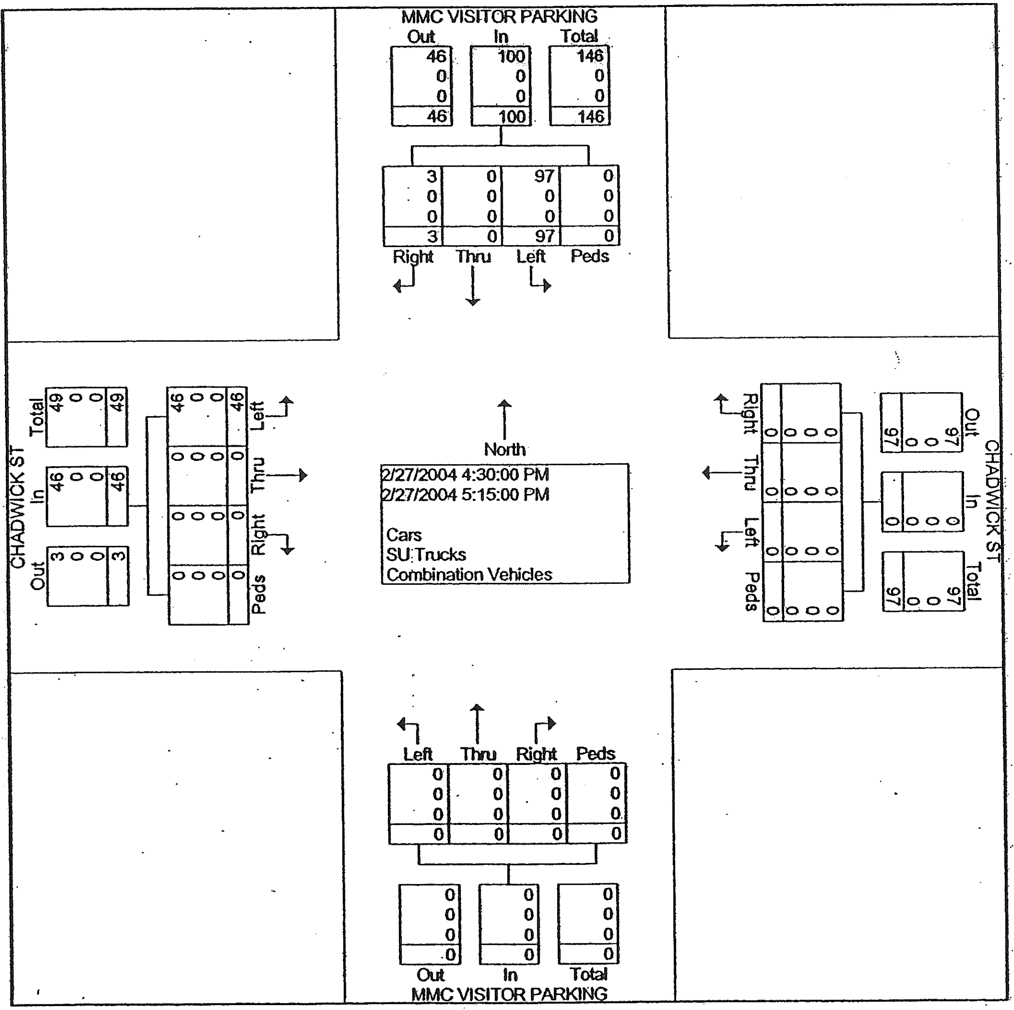
Gorrill-Palmer Consulting Engineers, Inc
15 Shaker Road
Gray, ME 04039
(207) 657-6910 FAX 657-6912

cation: Portland, Maine
d by: E. Bartlett

File Name : Visitor'sLotPM
Site Code : 00000317
Start Date : 02/27/2004
Page No : 1

Groups Printed- Cars - SU Trucks - Combination Vehicles

	MMC VISITOR PARKING From North					CHADWICK ST From East					MMC VISITOR PARKING From South					CHADWICK ST From West					
art Time	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	Int. Total
Factor	1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0		
4:30 PM	27	0	0	0	27	0	0	0	0	0	0	0	0	0	0	10	0	0	0	10	37
4:45 PM	31	0	1	0	32	0	0	0	0	0	0	0	0	0	0	9	0	0	0	9	41
Total	58	0	1	0	59	0	0	0	0	0	0	0	0	0	0	19	0	0	0	19	78
5:00 PM	20	0	1	0	21	0	0	0	0	0	0	0	0	0	0	16	0	0	0	16	37
5:15 PM	19	0	1	0	20	0	0	0	0	0	0	0	0	0	0	11	0	0	0	11	31
Grand Total	97	0	3	0	100	0	0	0	0	0	0	0	0	0	0	46	0	0	0	46	146
pprch %	97.0	0.0	3.0	0.0		0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0		100.0	0.0	0.0	0.0		
Total %	66.4	0.0	2.1	0.0	68.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.5	0.0	0.0	0.0	31.5	



Gorrill-Palmer Consulting Engineers, Inc
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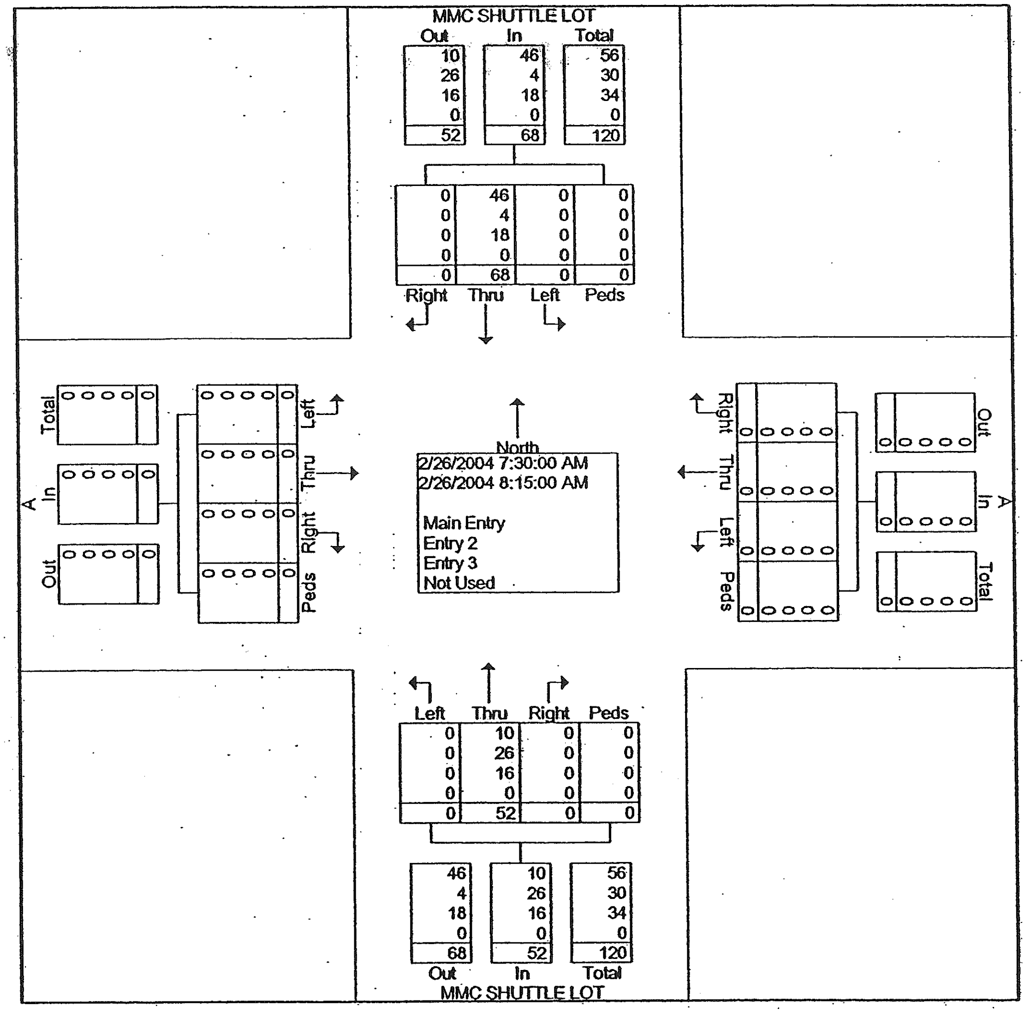
Gray, ME 04039
(207) 657-6910 FAX 657-6912

cation: Portland, Maine
unted by: E. Bartlett

File Name : ShuttleLotAM
Site Code : 00000317
Start Date : 02/26/2004
Page No : 1

Groups Printed- Main Entry - Entry 2 - Entry 3 - Not Used

	MMC SHUTTLE LOT From North					A From East					MMC SHUTTLE LOT From South					A From West					
tart Time	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	Int. Total
Factor	1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0		
7:30 AM	0	40	0	0	40	0	0	0	0	0	0	25	0	0	25	0	0	0	0	0	65
7:45 AM	0	23	0	0	23	0	0	0	0	0	0	24	0	0	24	0	0	0	0	0	47
Total	0	63	0	0	63	0	0	0	0	0	0	49	0	0	49	0	0	0	0	0	112
8:00 AM	0	4	0	0	4	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	5
8:15 AM	0	1	0	0	1	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	3
Grand Total	0	68	0	0	68	0	0	0	0	0	0	52	0	0	52	0	0	0	0	0	120
pprch %	0.0	100.0	0.0	0.0		0.0	0.0	0.0	0.0		0.0	100.0	0.0	0.0		0.0	0.0	0.0	0.0		
Total %	0.0	56.7	0.0	0.0	56.7	0.0	0.0	0.0	0.0	0.0	0.0	43.3	0.0	0.0	43.3	0.0	0.0	0.0	0.0	0.0	



2/26/2004 7:30:00 AM
2/26/2004 8:15:00 AM

Main Entry
Entry 2
Entry 3
Not Used

Gorrill-Palmer Consulting Engineers, Inc
15 Shaker Road
Gray, ME 04039
(207) 657-6910 FAX 657-6912

cation: Portland, Maine
unted by
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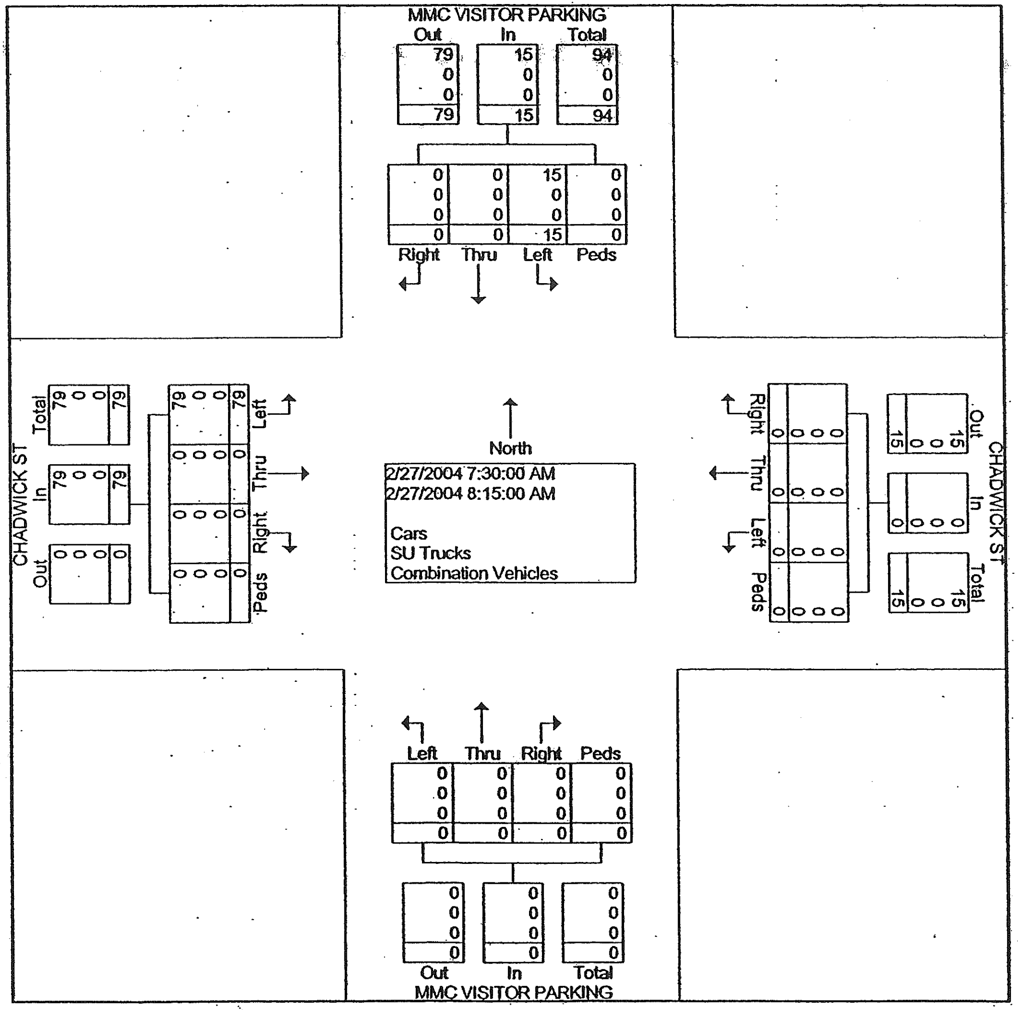
er

File Name : Visitor'sLotAM
Site Code : 00000317
Start Date : 02/27/2004
Page No : 1

Groups Printed- Cars - SU Trucks - Combination Vehicles

	MMC VISITOR PARKING From North					CHADWICK ST From East					MMC VISITOR PARKING From South					CHADWICK ST From West					
tart Time	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	Int. Total
Factor	1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0		
07:30 AM	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	13	0	0	0	13	14
07:45 AM	4	0	0	0	4	0	0	0	0	0	0	0	0	0	0	24	0	0	0	24	28
Total	5	0	0	0	5	0	0	0	0	0	0	0	0	0	0	37	0	0	0	37	42
08:00 AM	6	0	0	0	6	0	0	0	0	0	0	0	0	0	0	19	0	0	0	19	25
08:15 AM	4	0	0	0	4	0	0	0	0	0	0	0	0	0	0	23	0	0	0	23	27
Grand Total	15	0	0	0	15	0	0	0	0	0	0	0	0	0	0	79	0	0	0	79	94
Apprch %	100.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0		100.0	0.0	0.0	0.0		
Total %	16.0	0.0	0.0	0.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.0	0.0	0.0	0.0	84.0	



N: 317
roject Description: MMC
Project Location: Portland, ME
Date: Dec-03

Gorrill-Palmer Consulting Engineers, Inc.
P.O. Box 1237
15 Shaker Road
Gray, Maine 04039

Hospital
Land Use Code (LUC) 610

Beds (X): 480

Range of Rates (Max):

Time Period	ITE Trip Rate	Trip Ends	Directional Split		Directional Distribution	
			IN	OUT	IN	OUT
Weekday	T = 32.83(X)	15758	50%	50%	7879	7879
AM Peak Hour of Generator	T = 1.88(X)	902	65%	35%	587	316
PM Peak Hour of Generator	T = 2.51(X)	1205	39%	61%	470	735
Saturday	T = 21.04(X)	10099	50%	50%	5050	5050

'N:	317
ʼroject Description:	MMC
Project Location:	Portland, ME
Date:	Dec-03

Gorrill-Palmer Consulting Engineers, Inc.
P.O. Box 1237
15 Shaker Road
Gray, Maine 04039

Hospital
Land Use Code (LUC) 610

Beds (X): 490

Range of Rates (Max):

Time Period	ITE Trip Rate	Trip Ends	Directional Split IN	Directional Split OUT	Directional Distribution IN	Directional Distribution OUT
Weekday	T = 32.83(X)	16087	50%	50%	8043	8043
AM Peak Hour of Generator	T = 1.88(X)	921	65%	35%	599	322
PM Peak Hour of Generator	T = 2.51(X)	1230	39%	61%	480	750
Saturday	T = 21.04(X)	10310	50%	50%	5155	5155

JN: 317
Project Description: MMC
Project Location: Portland, ME
Date: Dec-03

Gorrill-Palmer Consulting Engineers, Inc.
P.O. Box 1237
15 Shaker Road
Gray, Maine 04039

Hospital
Land Use Code (LUC) 610

Difference Between 490 Beds and 480 Beds

Range of Rates (Max):

Time Period	ITE Trip Rate	Trip Ends	Directional Split		Directional Distribution	
			IN	OUT	IN	OUT
Weekday	T = 32.83(X)	328	50%	50%	164	164
AM Peak Hour of Generator	T = 1.88(X)	19	65%	35%	12	7
PM Peak Hour of Generator	T = 2.51(X)	25	39%	61%	10	15
Saturday	T = 21.04(X)	210	50%	50%	105	105

Tab 10

Bramhall Campus
Parking Study
Maine Medical Center
Portland, Maine

Prepared for
Maine Medical Center
22 Bramhall Street
Portland, Maine, 04102

December 2003
Revised April 2004

Prepared by

THOMAS
GORRILL
No. 4814

GP Gorrill-Palmer Consulting Engineers, Inc.
Traffic and Civil Engineering Services

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I. Executive Summary

The following Executive Summary is prepared for the reader's convenience, but is not intended to be a substitute for reading the full report.

Gorrill-Palmer Consulting Engineers, Inc. has been retained by Maine Medical Center to complete a parking inventory for the Bramhall campus of the Maine Medical Center to evaluate the adequacy of the parking supply upon completion of the proposed Charles Street Project planned at the Maine Medical Center in Portland. The proposed Obstetrics and Newborn Center will be bordered by Charles, Ellsworth, and Wescott Streets. The proposed building will consist of a total floor area of approximately 192,000 s.f. However, all of the functions proposed for the new center already exist within the campus but are crowded and do not meet current industry layout standards. Maine Medical Center is also planning to expand the existing parking garage at the corner of Gilman and Congress Streets by constructing a 512 space addition to the north. The location of the site is shown in Figure 1 of Appendix A.

A parking inventory was completed on Wednesday, June 17, 2000 from 6:00 AM to 4:00 PM in anticipation of this project. Although the study was completed in 2000, no material level of change has taken place at Maine Medical Center that would affect the findings of that study. Our findings are summarized below:

1. The current total off-street parking supply for Maine Medical Center was determined to be 2,146 parking spaces. The proposed expansion to the Gilman Street garage will be 512 spaces increasing the off street supply to 2,658 spaces.
2. The maximum off-street parking demand was 1,770 parking spaces, or 82 percent of the supply.
3. The total on-street parking supply in the vicinity of Maine Medical Center was determined to be 495 parking spaces.
4. The maximum demand for on-street parking was 318 parking spaces, or 64 percent of the supply. Approximately 57 of these parking spaces were filled by vehicles with MMC parking stickers. In addition, Gorrill-Palmer Consulting Engineers, Inc. estimates another 25 percent of the on-street parking is affiliated with MMC. Therefore, the current on-street parking demand associated with MMC is estimated to be 137 parking spaces or 28 percent of the current supply. This peak demand occurred form 8 to 9 AM. The overall peak demand for MMC occurred from 11 AM to noon at which time there on-street usage by MMC is estimated at 116 spaces.
5. The overall parking demand is anticipated to increase by 38 spaces due to the project. This will result in a total maximum demand of 1,924 spaces in the 11 AM to noon peak hour for MMC.
6. The total forecast MMC parking demand of 1,924 spaces represents 72% of the proposed 2,658 off-street supply proposed for MMC. This demand rate is

below the recommended industry standard that the demands not exceed 85 percent of the supply to allow for circulation and finding the remaining parking spaces.

7. Although Maine Medical Center's forecast parking supply falls within the recommended range, Gorrill-Palmer Consulting Engineers, Inc. recognized some areas where improvements could be made. Based on these observations, we recommend the following improvements:

   - The Visitor's Lot is overcrowded, causing visitors to park in walkways and driveways, and making it difficult to maneuver a vehicle through the lot. Gorrill-Palmer Consulting Engineers, Inc. recommends that visitors be allowed to park in the proposed parking lot expansion and signs should be posted at the entrance to the Visitor's Lot, directing traffic to this location when the Visitor's Lot is full. In addition, Gorrill-Palmer Consulting Engineers, Inc. recommends that patients be directed to park in the proposed garage in their pre-visit materials.

   - The majority of on-street parking is currently one-hour parking. In addition, many visitors are disregarding parking regulations and are parking in one-hour parking spaces for extended periods of time. Recently installed meters on Bramhall Street have helped alleviate this issue significantly. Gorrill-Palmer Consulting Engineers, Inc. recommends that strict enforcement of parking regulations be undertaken for all on-street locations and consideration be given to additional meters.

II. Introduction

Gorrill-Palmer Consulting Engineers, Inc. has been retained by Maine Medical Center to complete a parking inventory for the Bramhall campus of the Maine Medical Center to evaluate the adequacy of the parking supply upon completion of the proposed Charles Street Project planned at the Maine Medical Center in Portland. The proposed Obstetrics and Newborn Center will be bordered by Charles, Ellsworth, and Wescott Streets. The proposed building will consist of a total floor area of approximately 192,000 s.f. However, all of the functions proposed for the new center already exist within the campus but are crowded and do not meet current industry layout standards. Maine Medical Center is also planning to expand the existing parking garage at the corner of Gilman and Congress Streets by constructing a 512 space addition to the north. The location of the site is shown in Figure 1 of Appendix A.

The area studied by Gorrill-Palmer Consulting Engineers, Inc. includes the following off-street locations:

- Ramp Parking Garage off Gilman Street
- Medical Office Building (MOB) Lot
- St. John Street Lot (Union Station)
- Visitor's Lot
- Admitting Lot
- Emergency Lot
- Medical Students Lot
- Gilman Street Lot
- MMC Development Office Lot
- MRI Center Lot (Dana Center)

The study area also includes the following on-street locations:

- Chadwick Street (Bramhall to West)
- West Street (Vaughan to Western Promenade)
- Western Promenade (Bramhall to Carroll)
- Vaughan Street (West to Bramhall)
- Brackett Street (Vaughan to Bramhall)
- Bramhall Street (Vaughan to Western Promenade)
- Gilman Street (s/o Congress Street)
- Congress Street (Bramhall to Gilman)
- Crescent Street
- Ellsworth Street
- Hill Street
- Ramp (Gilman to Charles)

A map of the study area is included in Appendix B.

III. Data Collection

Gorrill-Palmer Consulting Engineers, Inc. surveyed the study area discussed above to determine the parking supply for each of the locations. Inventory sheets were then drawn up with each space marked separately on the inventory sheet. On Wednesday, June 17, 2000, Gorrill-Palmer Consulting Engineers, Inc. completed a parking inventory of the locations mentioned above. Although the study took place in 2000, no material level of change has taken place at Maine Medical Center that would affect the findings of the study. The inventory took place from 6:00 AM to 4:00 PM. Each lot and street was checked every hour to determine whether or not the parking spaces were occupied. When a space was occupied, the license plate was recorded in the corresponding space on the inventory sheet.

After completing the inventory, the data was compiled and analyzed. The supply and demand were calculated and compared for each location for each hour of the study. A discussion of the supply versus demand for each lot is included in the following sections.

IV. Parking Supply

Gorrill-Palmer Consulting Engineers, Inc. surveyed the lots and streets mentioned in the introduction of this report to determine the supply for each location. In areas where parking spaces were striped, the number of spaces was counted and recorded. In areas where metered parking was set-up, the number of meters and vehicles per meter were counted and recorded. In areas where there were no stripes or meters, the length of the space available for parking was measured. Assuming that an average vehicle requires 25 feet to parallel park, the number of feet of curb side parking was divided by 25 to determine the number of vehicles which could park in a given location. A discussion of the supply determined by Gorrill-Palmer Consulting Engineers, Inc. for each of the locations mentioned in the introduction is included below.

Off-street

Currently, based on data furnished by Maine Medical Center and data collected by Gorrill-Palmer Consulting Engineers, Inc., there are approximately 2,146 off-street parking spaces for the hospital. The locations of these spaces are shown in the table below and are discussed in more detail in the following paragraphs. After completion of the development, a total of 2,658 off-street parking spaces will be available for Maine Medical Center with the addition of a 512 car garage adjacent to the existing garage.

Off-street Parking Supply	
Location	**Number of Available Spaces**
Ramp Parking Garage	1225
MOB Lot	207
St. John Street Lot (Union Station)	283
Visitor's Parking Lot	329
Admitting	8
Emergency	16
Medical Students Lot	24
Gilman Street Lot	30
MMC Development Office Lot	10
MRI Lot (Dana Center)	14
Proposed Garage	512
Total Available Spaces	**2,658**

Ramp Parking Garage

The Ramp Parking Garage is located on the west side of Maine Medical Center and contains 1,225 parking spaces for Maine Medical Center medical staff and volunteers. Sixteen parking spaces on level G are used for valet parking only by the emergency room. Parking in this garage requires a permit. A permit for this garage also allows for parking in the Medical Office Building (MOB) Lot and St. John Street Lot when the Ramp Parking Garage is full.

Proposed Expansion to the Ramp Parking Garage

A 512 car expansion to the Ramp parking garage is proposed with access from Congress Street and Crescent Street.

MOB Lot

The MOB Lot is located at the corner of Congress Street and Forest Street, across from the Ramp Parking Garage. This garage contains a total of 434 parking spaces. It is divided by chains and posts into two parking areas, each with its own entrance. The lower levels contain 207 parking spaces for Maine Medical Center employees. A permit is required to park in this section of the lot. The two top levels contain 227 parking spaces and are used by private physicians at the Medical Office Building and their patients. These parking spaces are not currently available for use by Maine Medical Center employees.

St. John Street Lot (Union Station)

St. John Street Lot, listed as a source of parking in the table above, is located behind Goodwill, off Saint John Street. It is used by Goodwill, Margaritas Restaurant, and Hair It Is Salon. The rear section of this lot, containing 283 parking spaces, is used by Maine Medical Center to accommodate overflow in the Ramp Parking Garage. Employees are instructed to park in this lot when the Ramp Garage is filled. The Maine Medical Center runs a shuttle from the St. John Street Lot to the hospital.

Visitor's Lot

The Visitor's Lot is located on the east side of the hospital off of Chadwick Street. This lot contains 329 parking spaces with an hourly rate of $0.35 and a maximum payment of $3.50 per day. This lot is used by visitors to Maine Medical Center, who are parking for a short time to visit, drop-off, or pick-up patients. It is currently the most congested off-street parking location at Maine Medical Center.

Admitting Lot

The Admitting Lot contains 8 striped parking spaces with a 15-minute time limit. The employee shuttle pick-up is also located on the curb in this lot.

Emergency Lot

The Emergency Lot is used mainly for ambulance and EMT parking, and contains 16 parking spaces. There are 10 ambulance only parking spaces in this lot. In addition, there are 6 valet parking spaces located in this lot used by emergency room patients. When these six parking spaces have been filled, valets park vehicles on level G of the Ramp Parking Garage.

Medical Students Lot

The Medical Students lot is located on the west side of Chadwick Street between West Street and Pine Street. This lot contains 24 parking spaces used by medical students at Maine Medical Center.

Gilman Street Lot

The Gilman Street Lot is located in the rear of the hospital and can be accessed from Gilman Street or from a ramp off of Charles Street. This parking lot contains 30 parking spaces used by Maine Medical Center employees. In addition, this lot contains a large area used for truck access, delivery, and pick-up.

MMC Development Office Lot

The MMC Development Office Lot is located in back of the Development Office, off of Vaughan Street. This lot contains 10 parking spaces for employees of the MMC Development Office.

MRI Center Lot

The MRI Center Lot is located at the rear of the hospital and can be accessed from Bramhall Street and requires an access card to enter. This lot contains 14 striped parking spaces used by patients of the MRI Center. In addition, there is ample space for an additional 8 vehicles to park temporarily along the curb for drop-off and pick-up of patients.

On-street

Based on data furnished by Maine Medical Center and data collected by Gorrill-Palmer Consulting Engineers, Inc., there are approximately 495 on-street parking spaces located on the following streets surrounding the hospital:

On-street Parking Supply	
Location	Number of Available Spaces
Chadwick Street (Bramhall to West)	49
West Street (Vaughan to Western Promenade)	44
Western Promenade (Bramhall to Carroll)	69
Vaughan (West to Bramhall)	61
Brackett (Vaughan to Bramhall)	11
Bramhall (Congress to Western Promenade)	99
Gilman Street (s/o Congress)	51
Congress (Bramhall to Gilman)	64
Crescent Street	13
Ellsworth Street	8
Hill Street	18
Ramp (Gilman to Charles)	8
Total Available Spaces	**495**

Chadwick Street

There are a total of 49 parking spaces on Chadwick Street between Bramhall Street and West Street. 8 of the 49 spaces are metered spaces. These spaces are located on the east side of the street between Bramhall Street and the entrance to the Visitor's Lot. The remaining spaces are all one-hour parking spaces.

West Street

West Street has a total of 44 one-hour parking spaces between Vaughan Street and the Western Promenade.

Western Promenade

The Western Promenade has a total of 69 parking spaces between Bramhall Street and Carroll Street. All of these spaces are one-hour parking. Also, a small loop exists off the west side of the Western Promenade, which also contains one-hour parking spaces.

Vaughan Street

Vaughan Street has a total of 55 one-hour parking spaces from West Street to Bramhall Street. In addition, there are two 5-minute, handicapped parking spaces located in front of the Portland Urological Associates Building. There are also four 15-minute parking spaces located near the corner of Vaughan Street and Brackett Street.

Brackett Street

Brackett Street has a total of 11 metered parking spaces from Vaughan Street to Bramhall Street.

Bramhall Street

On the date the parking survey took place, Bramhall Street had a total of 80 one-hour parking spaces between Congress Street and Western Promenade. In addition, there were 4 handicapped spaces located near the entrance to the hospital. These spaces do not have a posted time limit. Since the date of the data collection, the City has added 15 one-hour, metered parking spaces on Bramhall Street across from the MRI Center (Dana Center) lot. Theses meters have significantly improved access to these spaces.

Gilman Street

Gilman Street has 25 one-hour parking spaces located on the west side of the street. There are an additional 26 parking spaces on the east side of the street, which do not have a posted time limit. Many of these parking spaces are used by Maine Medical Center employees who enter through the rear of the hospital through the Gilman Street Lot.

Congress Street

Congress Street has a total of 64 parking spaces with varying time limits. There are seven 2-hour parking spaces located between Gilman Street and Forest Street. There are four 15-minute parking spaces located at the corner of Weymouth Street and Congress Street. There are 28 one-hour parking spaces located on the north side of the street, and four one-hour parking spaces on the south side of the street. The remaining 21 parking spaces on the south side of the street do not have a posted time limit.

Crescent Street

Crescent Street has 13 one-hour parking spaces located mainly on the west side of the street.

Ellsworth Street

At the time of the study, Ellsworth Street contained 16 one-hour parking spaces. The proposed development will involve the removal of 8 of these parking spaces, leaving 8 one-hour parking spaces on this street. The vehicles currently using this street to park and visit Maine Medical Center will be reassigned to the proposed garage.

Hill Street

Hill Street contains 18 one-hour parking spaces. These spaces are used by residents on this street and MMC visitors.

Ramp

The ramp, located between Gilman Street and Charles Street on the west side of the hospital, has 8 parking spaces on the east side of the ramp. These parking spaces are used by Maine Medical Center employees. No-parking signs are posted for two of these spaces. However, several vehicles parked in these spaces throughout the day and no tickets were noticed on the vehicles.

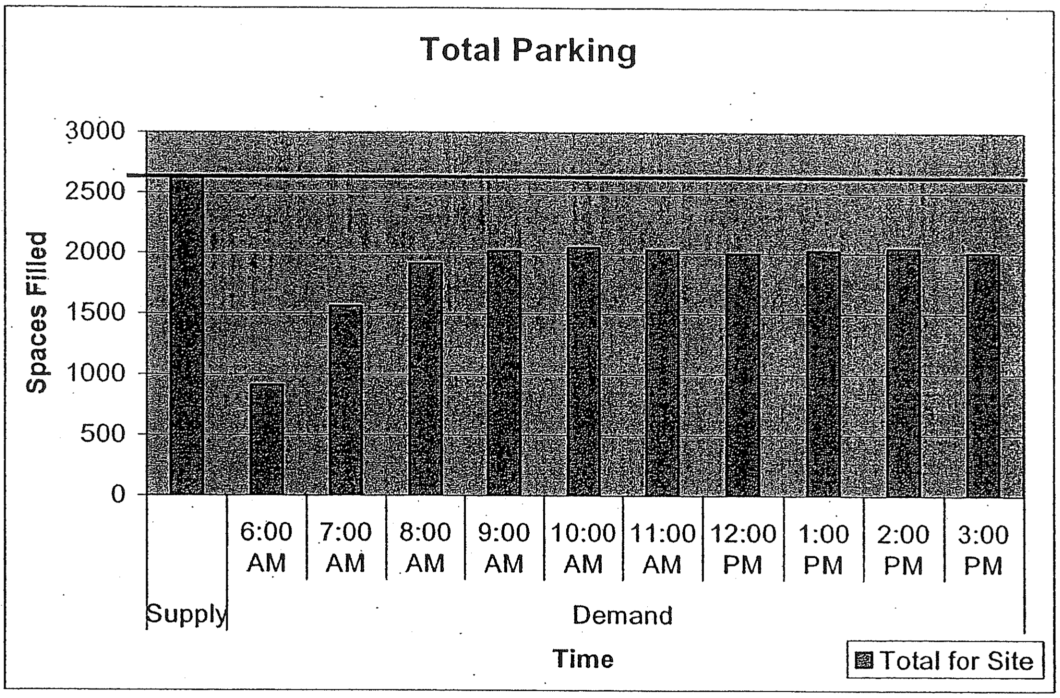
V. Parking Demand

On Wednesday, June 17, 2000, Gorrill-Palmer Consulting Engineers, Inc. completed the parking inventory of the lots mentioned in the table above, as well as the streets surrounding the hospital. Although this study was conducted in 2000, no material level of change has taken place at Maine Medical Center that would affect the findings of this study. The inventory took place from 6:00 AM to 4:00 PM. Each lot and street was checked every hour to determine whether or not each parking space was occupied. If a space was occupied, the license plate was recorded in the corresponding space on the inventory sheet.

After completing the inventory, the data was compiled and analyzed. The demand was then determined for each location for each hour. The demand for the off-street and on-street parking was also calculated for each hour. A summary of the parking supply versus demand is shown in the following table.

		Parking Demand Summary									
Location	Supply	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM
MOB Lot	207	21	86	147	160	166	168	170	**170**	167	152
Ramp Garage	1225	528	944	1028	**1033**	1013	1019	983	982	983	1013
All Garages	1432	549	1030	1175	**1193**	1179	1187	1153	1152	1150	1165
St. John Street Lot	283	12	88	153	171	183	187	188	**191**	187	172
Visitor's Lot	329	73	112	184	266	307	312	325	**331**	**331**	301
Small Lots	102	33	52	82	81	73	**84**	70	79	74	78
Off-street	2146	667	1282	1594	1711	1742	**1770**	1736	1753	1742	1716
On-street	495	243	277	**318**	309	305	261	263	268	302	288
Total for Site	2641	910	1559	1912	2020	**2047**	2031	1999	2021	2044	2004

The following table summarizes the total supply and demand for each hour of the inventory for the entire site.

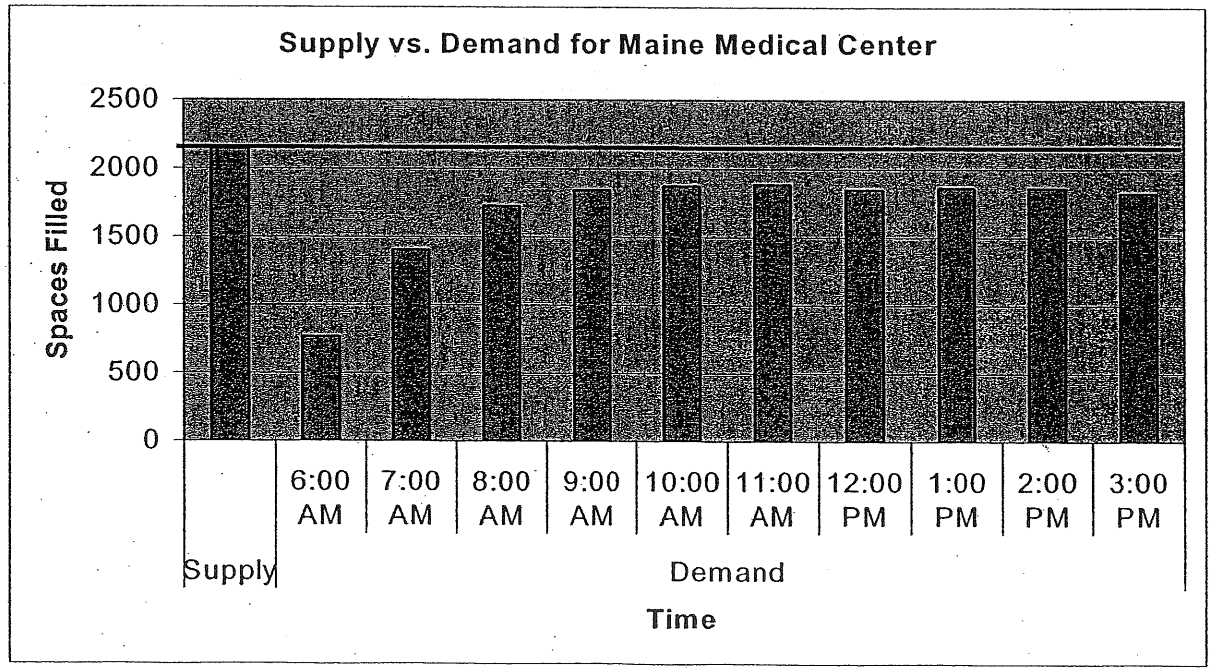


The highest demand for the hospital was determined to occur at 10:00 AM, when there is a demand of 2,047 spaces or 78 percent of the supply. However, this observed parking demand includes vehicles that are not associated with the Maine Medical Center. While conducting our survey, Gorrill-Palmer Consulting Engineers, Inc. also noted whenever a MMC sticker was placed on a vehicle parked on the street. The following table summarizes the number of parking spaces filled by vehicles with a MMC sticker.

Street	Supply	Number of Stickers									
		6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM
Chadwick	49	5	6	5	6	7	5	5	3	3	3
West	44	3	3	3	4	3	5	4	4	4	3
Vaughan	61	6	6	6	6	6	4	4	3	3	2
Brackett	11	0	0	0	0	0	0	0	0	0	0
Bramhall	99	10	14	15	12	13	10	10	10	10	10
Gilman	51	8	11	12	14	15	15	17	16	16	11
Congress	64	4	4	4	3	3	3	3	2	2	3
Crescent	13	2	2	2	3	2	1	0	1	1	1
Ellsworth	16	1	3	3	4	4	3	2	2	2	0
Hill	18	1	1	1	1	1	2	1	1	1	0
Western Promenade	69	1	2	3	3	3	3	2	2	2	1
Total	495	41	52	54	56	57	51	48	44	44	34

As shown in the table above, the current on-street parking demand for vehicles with MMC stickers is approximately 57 parking spaces or 18 percent of the on-street demand. MMC stickers are placed only on vehicles belonging to employees of the Maine Medical Center. Therefore, in order to determine the off-street demand for MMC, these vehicles should be added to the off-street demand calculated above. In addition, Gorrill-Palmer Consulting Engineers, Inc. estimates that an additional 80 parking spaces or 25 percent of the total on-street parking demand is due to MMC patients, visitors and staff. This number must also be added to the off-street parking to determine the actual off-street parking demand. The following table and chart summarize the current off-street parking demand with these numbers added.

Location	Supply	Demand									
		6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM
Off-street	2146	667	1282	1594	1711	1742	1770	1736	1753	1742	1716
MMC Stickers On-street	N/A	41	52	54	56	57	51	48	44	44	34
Visitors On-street	N/A	61	70	80	77	76	65	66	67	76	72
Total	2146	769	1404	1728	1844	1875	1886	1850	1864	1862	1822



As shown in the previous table, the actual Maine Medical Center parking demand is currently 1,886 parking spaces or approximately 88 percent of the parking supply.

Future Demand

The current off-street parking demand was estimated to be 1,886 parking spaces, or 88 percent of the supply as discussed above. Maine Medical Center continues its efforts to decompress the Bramhall campus by redirecting outpatients from the Bramhall campus to its Brighton, Scarborough and Falmouth campuses. The relocation of patient activity from the Bramhall campus to the other campuses helps alleviate parking demand and congestion at Maine Medical Center's main campus, which are ongoing concerns. Routine outpatient activity is redirected toward satellite campuses to free up Maine Medical Center's clinical resources for inpatient demand due Maine Medical Center's role as Maine tertiary care center. Currently, Maine Medical Center plans to move its endoscopy and outpatient surgery facilities to the Scarborough and Brighton Campuses. This will result in a reduction of 7,500 to 8,000 patient visits per year. Although we can not take credit for this relocation, it is an illustration of the Maine Medical Center's continuing commitment to decompress the Bramhall campus.

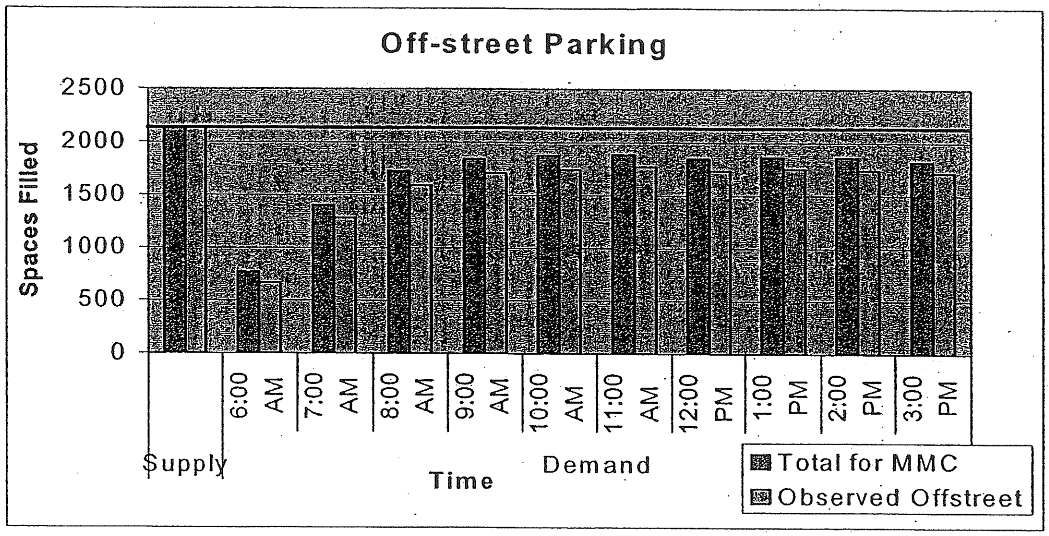
The proposed Obstetrics and Newborn Center will consist of a total floor area of approximately 192,000 s.f. However, all of the functions proposed for the new center already exist within the campus but are crowded and do not meet current industry layout standards. Based on information furnished by MMC, the inpatient population is expected to grow from 480 to 490 patients or 2% between 2003 and 2005 (1% per year). The outpatient activity has been proportional to the inpatient activity in the last decade. This does not necessarily reflect the national trend, which generally shows outpatient increasing more than inpatient, because a significant portion of the increase in outpatient activity has been shifted away from the Bramhall campus to the Brighton and Scarborough campuses as discussed above.

The staffing load is driven by the number of patients and is therefore not expected to increase, however we have assumed a 2% increase to be conservative.

The overall parking demand on campus will be forecast to increase by 2%, or 38 spaces. Thus, the total demand is forecast to be 1,924 spaces upon completion of the expansion.

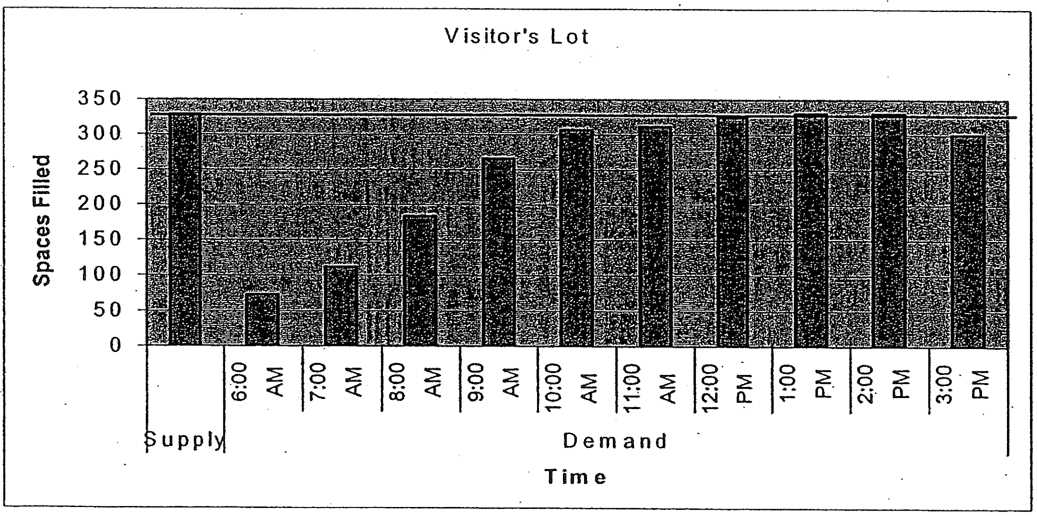
Off-Street

The following table summarizes the current supply and hourly parking demand for all off-street parking:



Visitor's Lot

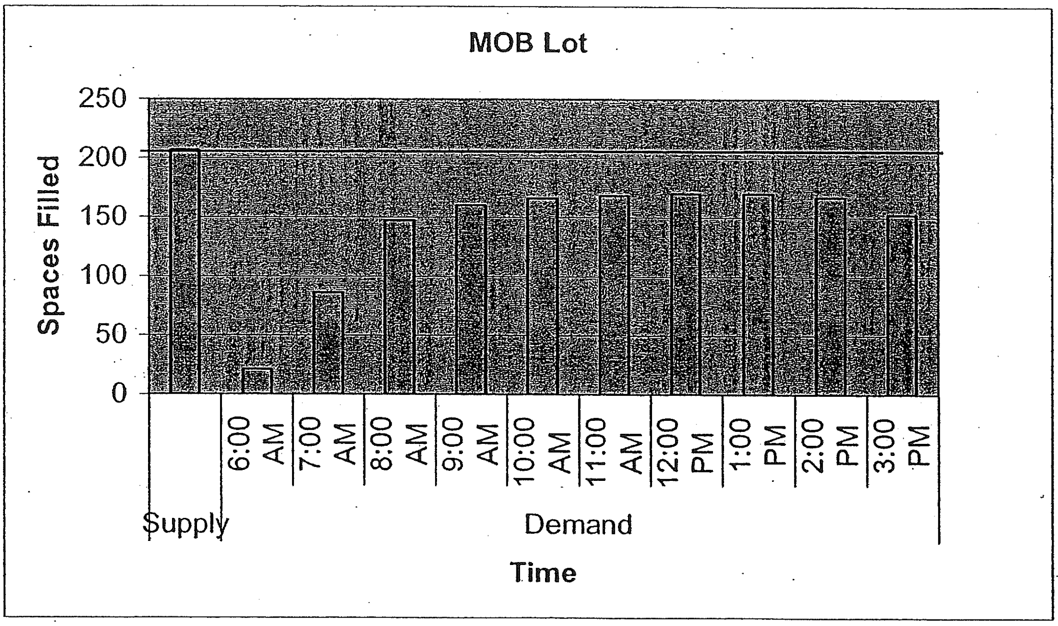
The following graph summarizes the supply and hourly demand for the Visitor's Lot:



The supply for the Visitor's Lot was determined to be 329 parking spaces. However, the highest demand for the Visitor's Lot was found to be 331 parking spaces. This level of demand occurred between 1:00 PM and 3:00 PM. During this time, cars were parked illegally in the driveways and walkways. This made maneuvering a vehicle through the lot difficult and forced pedestrians to walk around vehicles parked in crosswalks. Often times, cars would queue at the entrance to the Visitor's Lot, waiting for a car to leave so that they might enter. This queue of cars often backed up traffic attempting to drive down Chadwick Street. It is therefore, the opinion of Gorrill-Palmer Consulting Engineers, Inc. that Maine Medical Center is not meeting its parking demand for visitors. Gorrill-Palmer Consulting Engineers, Inc. recommends posting signs at the entrance to the visitor's lot directing traffic to the proposed addition to the parking garage. This may reduce the queuing of cars on Chadwick Street and prevent vehicles from parking in walkways and driveways. In addition, Gorrill-Palmer Consulting Engineers, Inc. recommends that patients be directed to park in the proposed garage on Congress Street in their pre-visit materials.

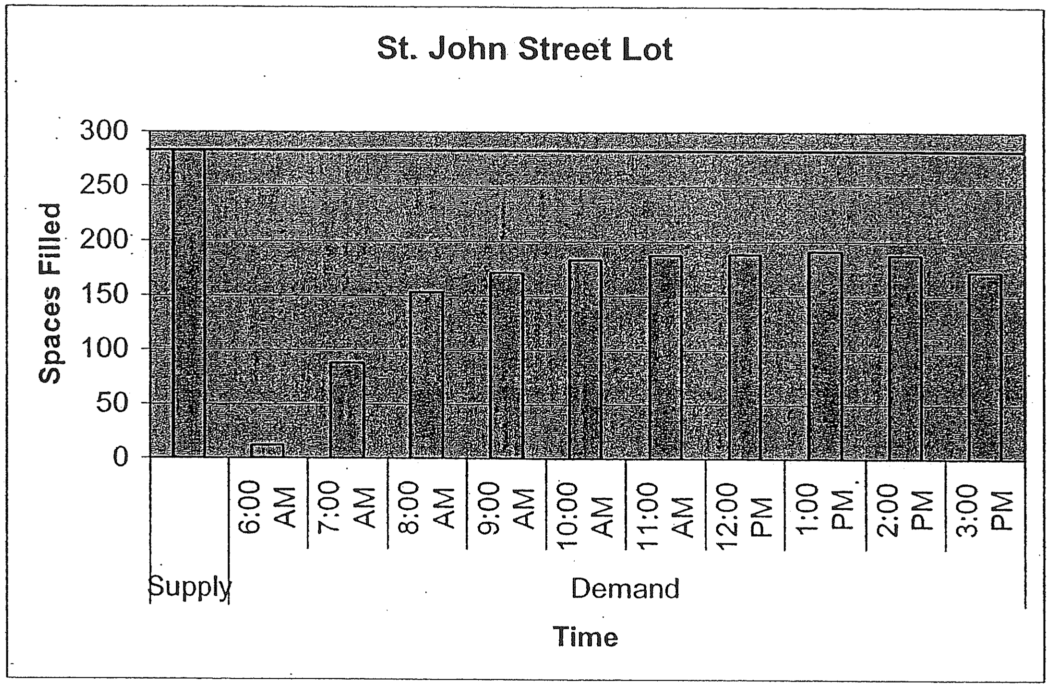
MOB Lot

Gorrill-Palmer Consulting Engineers, Inc. also determined that the MOB lot is currently less than 82 percent full at its peak. Gorrill-Palmer Consulting Engineers, Inc. recommends Maine Medical Center take steps to encourage more employees to park in this lot. The following table summarizes the hourly parking supply and demand of the MOB Lot.



St. John Street Lot

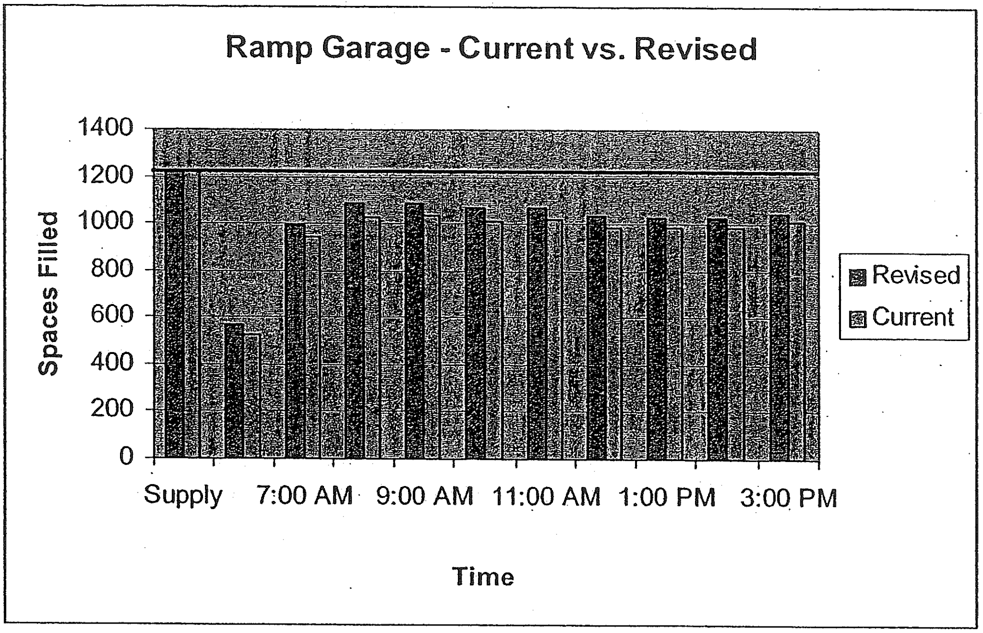
The maximum demand for the St. John Street Lot was 191 parking spaces, or 67 percent of the supply. Currently, Maine Medical Center runs a shuttle from the St. John Street Lot to the hospital for its employees. It is the recommendation of Gorrill-Palmer Consulting Engineers, Inc. that Maine Medical Center encourage its employees to park in this lot and take advantage of this service. The following table summarizes the hourly parking supply and demand for the Saint John Street Lot.



Ramp Parking Garage

The maximum demand for the Ramp Parking Garage was 1,033 parking spaces, or 84 percent of the supply. Although this high demand would seem to preclude additional vehicles in this parking garage, the peak for this lot occurs early in the day, between 8:00 and 9:00 AM, while there is a turnover of staff at Maine Medical Center. Between the hours of 1:00 and 3:00 PM, this garage is only approximately 80 percent full, leaving 242 empty spaces. Adding the employee vehicles, which currently park on the street, would increase the parking demand for this lot to only 1,089 parking spaces or 88 percent of the supply. Gorrill-Palmer Consulting Engineers, Inc. therefore, feels that Maine Medical Center should encourage its employees to park in this garage rather than on the street.

The following table summarizes the hourly parking supply and demand for the Ramp Garage in its current condition and with the improvements recommended by Gorrill-Palmer Consulting Engineers, Inc.



MRI Center Lot

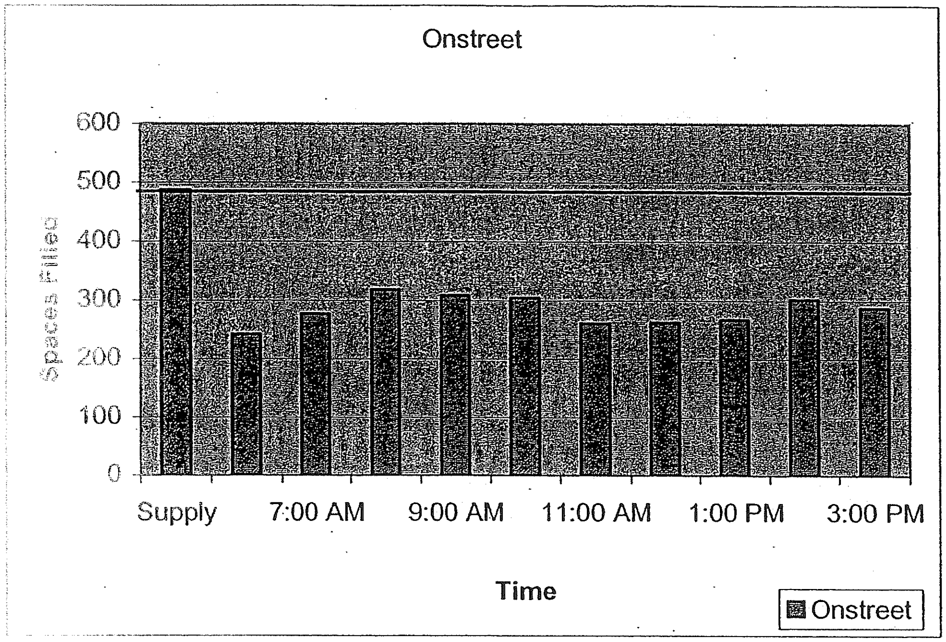
Currently, the rear lot off of Bramhall Street is striped for 14 spaces for patients. However, there is enough space along the curb for an additional 8 vehicles to park temporarily for drop-off.

Proposed Parking Garage

As mentioned above, Maine Medical Center is not currently meeting the parking demand for its visitors in the off-street lots. The surrounding neighborhood is concerned that a large number of visitors and patients are using on-street parking. The proposed garage on Congress Street, with 512 parking spaces, is anticipated to relieve overcrowding in the visitor's lot and provide an additional parking area for Maine Medical Center visitors. The addition of this garage will raise the total Maine Medical Center parking supply to 2,658 parking spaces. Currently, the total demand for Maine Medical Center is 1,886 spaces or 71 percent of the future supply after completion of the garage. Typically, no more than 85 percent occupancy is desired in order to allow for circulation and finding remaining parking spaces. With its proposed improvements, Maine Medical Center will meet this criterion.

On-Street

The following graph summarizes the supply and hourly parking demand for on-street parking:



Western Promenade

Currently, the Western Promenade contains enough space for 69 parking spaces. Throughout the day, no more than 30 percent of these spaces were filled.

Ellsworth Street

With its close proximity to the entrance to the hospital, Ellsworth Street is one of the most frequently used parking areas for visitors to Maine Medical Center. Ellsworth Street contains enough space for 16 vehicles to park legally in one-hour parking spaces. However, eight of these parking spaces will be lost due to construction. In addition, many vehicles remained parked in these spaces for well over the time limit without being ticketed. In addition, there are several curb-side locations which are marked as no-parking zones for bus stops, fire hydrants, etc. Throughout the day, particularly during peak parking times for the Visitor's Lot, visitors parked in these no-parking zones. It is the opinion of Gorrill-Palmer Consulting Engineers, Inc. that strict enforcement of parking regulations combined with the increased supply proposed as part of this project should reduce this problem.

Chadwick Street

Chadwick Street contains enough curb-side space for 20 vehicles to park legally. However, between the hours of 12:00 and 3:00 PM, when the Visitor's Lot is full, several vehicles were seen parked illegally across driveways and fire hydrants along this street. It is therefore, the opinion of Gorrill-Palmer Consulting Engineers, Inc. that strict enforcement of parking regulations should be upheld for Chadwick Street. In addition, signs should be posted near the entrance of the Visitor's Lot, directing traffic toward the new parking garage. Patients should also be instructed to park in the new garage in their pre-visit materials.

Bramhall Street

Bramhall Street contains enough curb-side space for 84 vehicles to park legally in one hour parking spaces. However, many vehicles were observed parking for several hours at a time. In addition, this street seemed to be a favorite for vehicles with MMC parking stickers and visitors to the Maine Medical Center. It is the opinion of Gorrill-Palmer Consulting Engineers, Inc. that strict enforcement of parking regulations combined with the increased supply proposed as part of this project, should reduce this problem.

Gilman Street

Currently, the majority of the west side of Gilman Street is used by Maine Medical Center employees with MMC parking stickers. These spaces do not have a time limit and are therefore often preferred over parking in the St. John Street Lot and riding the shuttle. This greatly reduces the number of on-street parking spaces available for residents and patrons to facilities on Gilman Street. MMC should strongly encourage its employees to avoid parking on this street and to park in the proposed expansion to the Ramp Garage or the St. John Street Lot.

VI. Conclusions

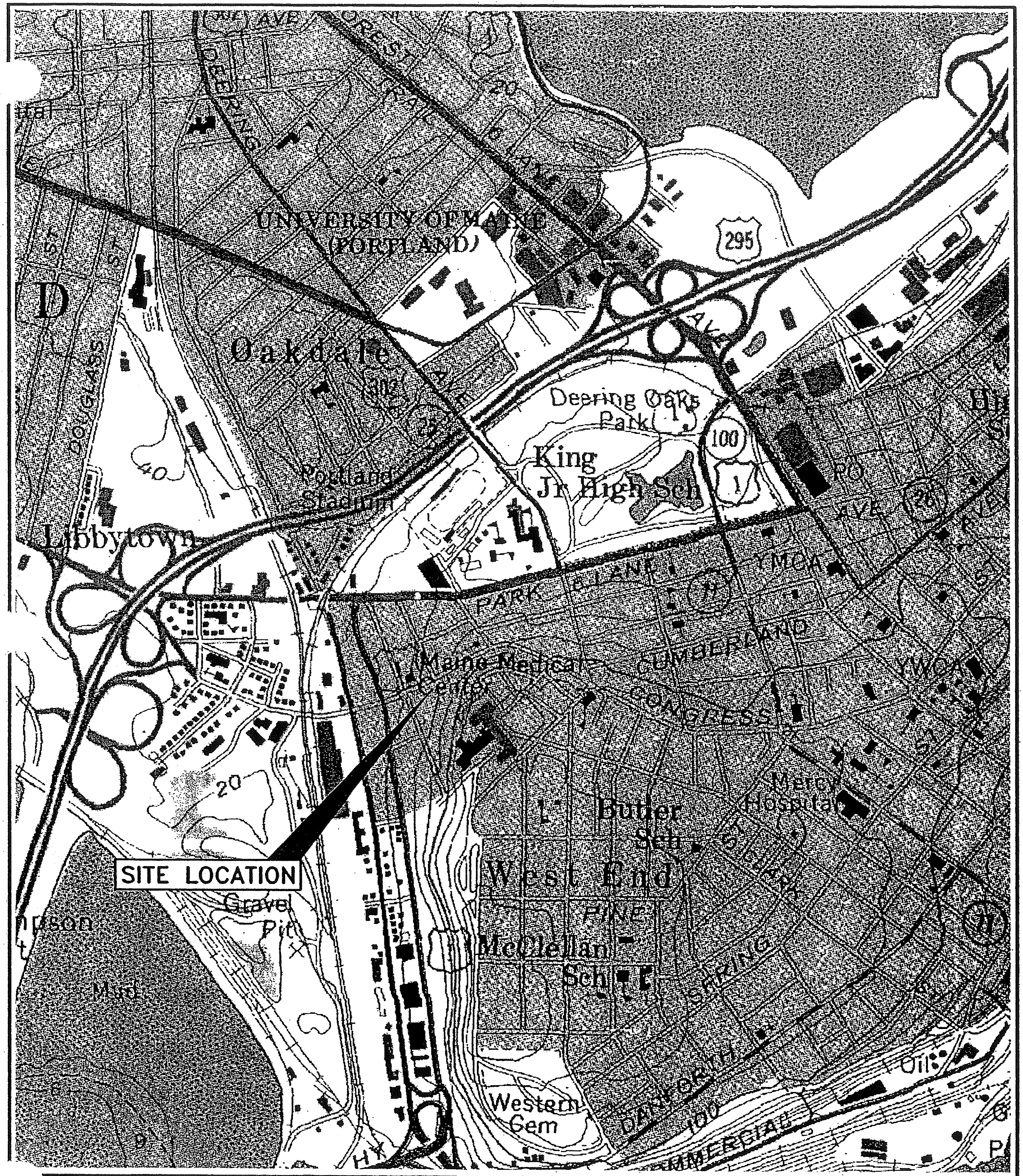
The following is a summary of the findings of Gorrill-Palmer Consulting Engineers, Inc.

1. The current total off-street parking supply for Maine Medical Center was determined to be 2,146 parking spaces. The proposed expansion to the Gilman Street garage will be 512 spaces increasing the off street supply to 2,658 spaces.
2. The maximum off-street parking demand was 1,770 parking spaces, or 82 percent of the supply.
3. The total on-street parking supply in the vicinity of Maine Medical Center was determined to be 495 parking spaces.
4. The maximum demand for on-street parking was 318 parking spaces, or 64 percent of the supply. Approximately 57 of these parking spaces were filled by vehicles with MMC parking stickers. In addition, Gorrill-Palmer Consulting Engineers, Inc. estimates another 25 percent of the on-street parking is affiliated with MMC. Therefore, the current on-street parking demand associated with MMC is estimated to be 137 parking spaces or 28 percent of the current supply. This peak demand occurred form 8 to 9 AM. The overall peak demand for MMC occurred from 11 AM to noon at which time there on-street usage by MMC is estimated at 116 spaces.
5. The overall parking demand is anticipated to increase by 38 spaces due to the project. This will result in a total maximum demand of 1,924 spaces in the 11 AM to noon peak hour for MMC.
6. The total forecast MMC parking demand of 1,924 spaces represents 72% of the proposed 2,658 off-street supply proposed for MMC. This demand rate is below the recommended industry standard that the demands not exceed 85 percent of the supply to allow for circulation and finding the remaining parking spaces.
7. Although Maine Medical Center's forecast parking supply falls within the recommended range, Gorrill-Palmer Consulting Engineers, Inc. recognized some areas where improvements could be made. Based on these observations, we recommend the following improvements:

   - ➢ The Visitor's Lot is overcrowded, causing visitors to park in walkways and driveways, and making it difficult to maneuver a vehicle through the lot. Gorrill-Palmer Consulting Engineers, Inc. recommends that visitors be allowed to park in the proposed parking lot expansion and signs should be posted at the entrance to the Visitor's Lot, directing traffic to this location when the Visitor's Lot is full. In addition, Gorrill-Palmer

Consulting Engineers, Inc. recommends that patients be directed to park in the proposed garage in their pre-visit materials.

- The majority of on-street parking is currently one-hour parking. In addition, many visitors are disregarding parking regulations and are parking in one-hour parking spaces for extended periods of time. Recently installed meters on Bramhall Street have helped alleviate this issue significantly. Gorrill-Palmer Consulting Engineers, Inc. recommends that strict enforcement of parking regulations be undertaken for all on-street locations and consideration be given to additional meters.



U.S.G.S. Location Map

Maine Medical Center - Portland, Maine

U.S.G.S. Portland-West, Maine-7.5 Minute Series (Topographic)

Design: JJB	Date: AUG 2003
Draft: DB	Job No.: 317
Checked: JJB	Scale: None

GP Gorrill-Palmer Consulting Engineers, Inc.

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Figure

1

Tab 11

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SUBJECT: Maine Medical Center – Central Utility Plant
Portland, Maine
Environmental Noise Study of Building Mechanical Equipment

Dear Tom,

This letter presents our environmental noise evaluation and control recommendations for the mechanical equipment in the proposed Central Utility Plant of Maine Medical Center. Based on the mechanical equipment information provided by your firm, we have developed a model which estimates sound levels produced by plant equipment and transmitted to nearby properties. The study locations are shown in SK-1 attached with this letter. The predicted sound levels are compared to the applicable noise criteria for the City of Portland, Maine. The estimated sound levels provided in this letter report include noise controls needed to ensure that plant sound levels do not exceed the Portland noise criteria as discussed below.

Criteria

There are two regulations known to be applicable to the City of Portland, ME. The first is the Maine Department of Environmental Protection Site Development Law and the second is the City of Portland Noise Ordinance.

The Maine DEP Site Development Law Chapter 375 Section 10-B (1) states that: *"This regulation [Control of Noise] applies to proposed developments within municipalities without a local quantifiable noise standard and in unorganized areas of the State…"* Since the City of Portland contains a quantifiable noise standard, the Maine DEP Site Development Law permits its preemption by the City ordinance as long as the City limits are not higher than 5 dBA above the MDEP limits.

The City of Portland Noise Ordinance states various sound limits depending on the zoning classification. The most conservative criteria, applicable to B2, B2b, B3, B3b zones, states that daytime sound levels (7 AM to 9 PM) should not exceed 60 dBA, and nighttime sound levels (9 PM to 7 AM) should not exceed 55 dBA. These criteria are within 5 dBA of the Maine DEP limits, therefore they are permitted by the MDEP Site Development Law.

However, the Portland Noise Ordinance does not set limits for all zones, including the R6 zone surrounding the power plant. Out of regard for the adjacent neighborhood, we have adopted the above-mentioned 60 dBA day / 55 dBA night noise limits for this study of Maine Medical Center Central Utility Plant noise. This is a reasonable and conservative course of action since the ambient sound in this area ranges between 57 and 63 dBA during the day, and between 54 and 62 dBA at night. (Sound data are taken from previous sound study report for MMC by Resource Systems Engineering). These levels are above the limits implying that the MMC addition will not be significant.

Facility Noise Analysis and Noise Control

We have estimated sound levels produced by outdoor mechanical equipment using computer spreadsheet modeling. The following is a list of equipment included in our study.

- Emergency Generators 2000 kW (2 units)
- Cooling Towers – 80% Fan Speed (6 cells)
- Chiller Room and Boiler Room Air Handling Units –(2 units)
- Chillers - 1200 Tons (3 units)
- Boilers - 1100 HP (3 units)
- Emergency Room Exhaust Fans – 1170 rpm (2 units)
- Other Mechanical Room Exhaust Fans – various (5 units)

Nearest residential neighbors are across Gilman Street, approximately 70 feet away from the façade of the plant.

Table 1 shows estimated sound levels at the selected study locations shown in SK-1 presuming implementation of recommended noise control equipment and methods. Table 2 in the appendix section also shows contributions of individual equipment items to total estimated sound levels at receptor locations.

The sound attenuators indicated in the mechanical equipment schedule have been used in developing our environmental noise model. In our modeling, we have used sound attenuators by Industrial Acoustics Company. Attenuators with similar dynamic insertion loss (DIL) values may be used. Note that certain sound attenuators shown in the drawings are not shown in the mechanical schedule.

Study Location	Total w/o Emergency Generators	Total with one Emergency Generator	Total with two Emergency Generators	Portland Nighttime Limit	Portland Daytime Limit
1	42	47	55	**55**	**60**
2	51	54	55	**55**	**60**
3	51	52	53	**55**	**60**

Table 1. Summary of predicted sound levels by the Central Utility Plant mechanical equipment to Study Locations shown in SK-1

Maximum plant sound levels occur when emergency generators are in operation for maintenance purposes. We expect that this will occur for approximately ½ hour per week during either daytime or nighttime hours. For most of the time, sound levels during the day and night will be approximately what is shown in the second column of Table 1.

We have provided additional noise control recommendations to ensure that sound levels will be within the nighttime limit set by the City of Portland. We assumed all other equipment to be in full operation day and night for our environmental noise model

Below are noise control measures needed to achieve the result shown in Table 1:

Emergency Generators

Emergency Generator Room Treatment
Mount sound absorbing panels on 50% of the emergency generator room walls. These can be Tectum with fiberglass backing as shown in SK-2.

Emergency Generator Room Intake
Install an 84" long sound attenuator model LFS by Industrial Acoustics Company (IAC).

Emergency Generator Discharge
Install the 60" long sound attenuator now shown in the drawings for the emergency room discharge. (IAC model LFS or equal)

Emergency Generator Exhaust
The critical grade exhaust muffler is adequate for noise control. Super critical grade muffler is not necessary.

Emergency Generator Room Roof Exhaust Fans
Install 36" long cylindrical sound attenuators on the discharges. These may be IAC model FCL or equal.

Install 36" long rectangular sound attenuators on the bypass air intake openings of the exhaust fans located at the roof level. Use of an acoustical louver is permitted.

Emergency Generator Room Exhaust
Install the 60" long sound attenuator now shown in the drawings on the propeller exhaust fans serving the emergency generator rooms. This may not be feasible and may require a different type of fan to enable installation of the recommended silencer. (IAC model LFS or equal)

Boiler Room

Boiler Room Intake
Install the 60" long sound attenuator now shown in the drawings on the boiler room air intake. (IAC model LFS or equal)

Boiler Room Relief Louver
Install the 60" long sound attenuator now shown in the drawings on the boiler room relief air opening. (IAC model LFS or equal)

Chiller Room

Chiller Room Intake
Install the 60" long sound attenuator now shown in the drawings on the chiller room air intake. (IAC model LFS or equal)

Chiller Room Exhaust
Install 36" long sound attenuator on the chiller room exhaust opening. (IAC model LFS or equal)

Cooling Towers

Our modeling has included the full operation of the four cooling tower cells now proposed plus operation of two future cells. Resulting sound levels are acceptable at 80% fan speed.

Metal Panel for the Front Façade of the Central Utility Plant

Upgrade the metal panels from 26 gauge to 22 gauge, this will reduce sound transmission from the utility plant equipment to the neighbors across the street.

All noise control recommendations are based on the preliminary design of the Central Utilities Plant. Should there be any changes to the equipment or design, we will provide more specific noise control recommendations where necessary to meet the day and nighttime noise limits.

Conclusions

With the above noise control recommendations implemented, sound levels associated with the proposed Maine Medical Center power plant will be conform to the City of Portland noise criteria.

If you have any questions, please contact us. Thank you.

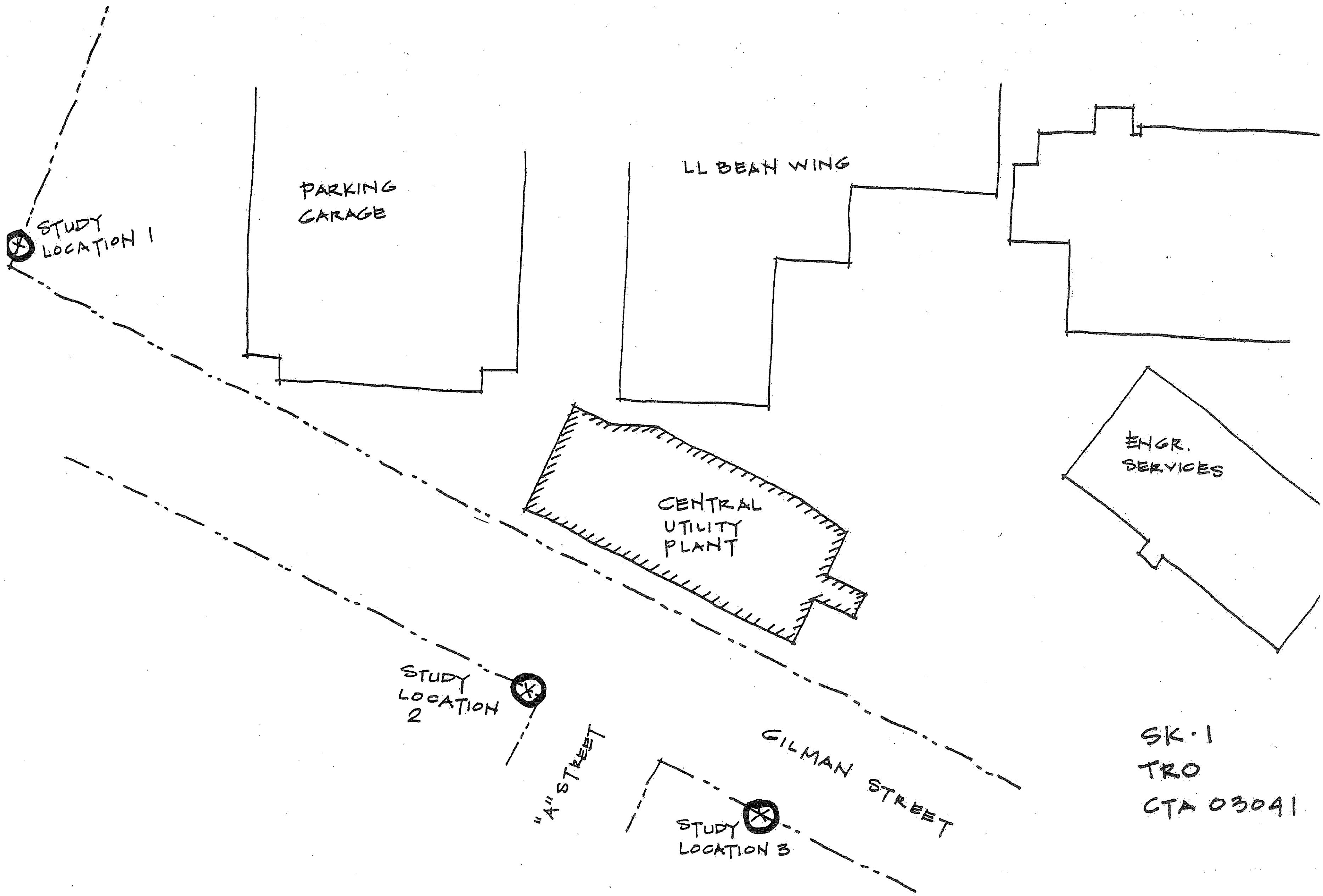
Sincerely,
CAVANAUGH TOCCI ASSOCIATES, INC.

Rose Mary Su
Staff Consultant

Gregory C. Tocci
Senior Consultant

RMS/gct/rms-03041-Maine Medical Center-Central Utility Plant-Env Noise Study and Rec 2

Appendix
Tables and Sketches



SK-1
TRO
CTA 03041

MAINE MEDICAL CENTER - CENTRAL UTILITY PLANT

CAVANAUGH
TOCCI
ASSOCIATES, INCORPORATED

CAVANAUGH
TOCCI
ASSOCIATES, INCORPORATED

327 F BOSTON POST ROAD, SUDBURY, MA 01776
TELEPHONE (978) 443-7871
FAX (978) 443-7873

JOB TRO - MAINE MEDICAL CENTER

SHEET NO. OF

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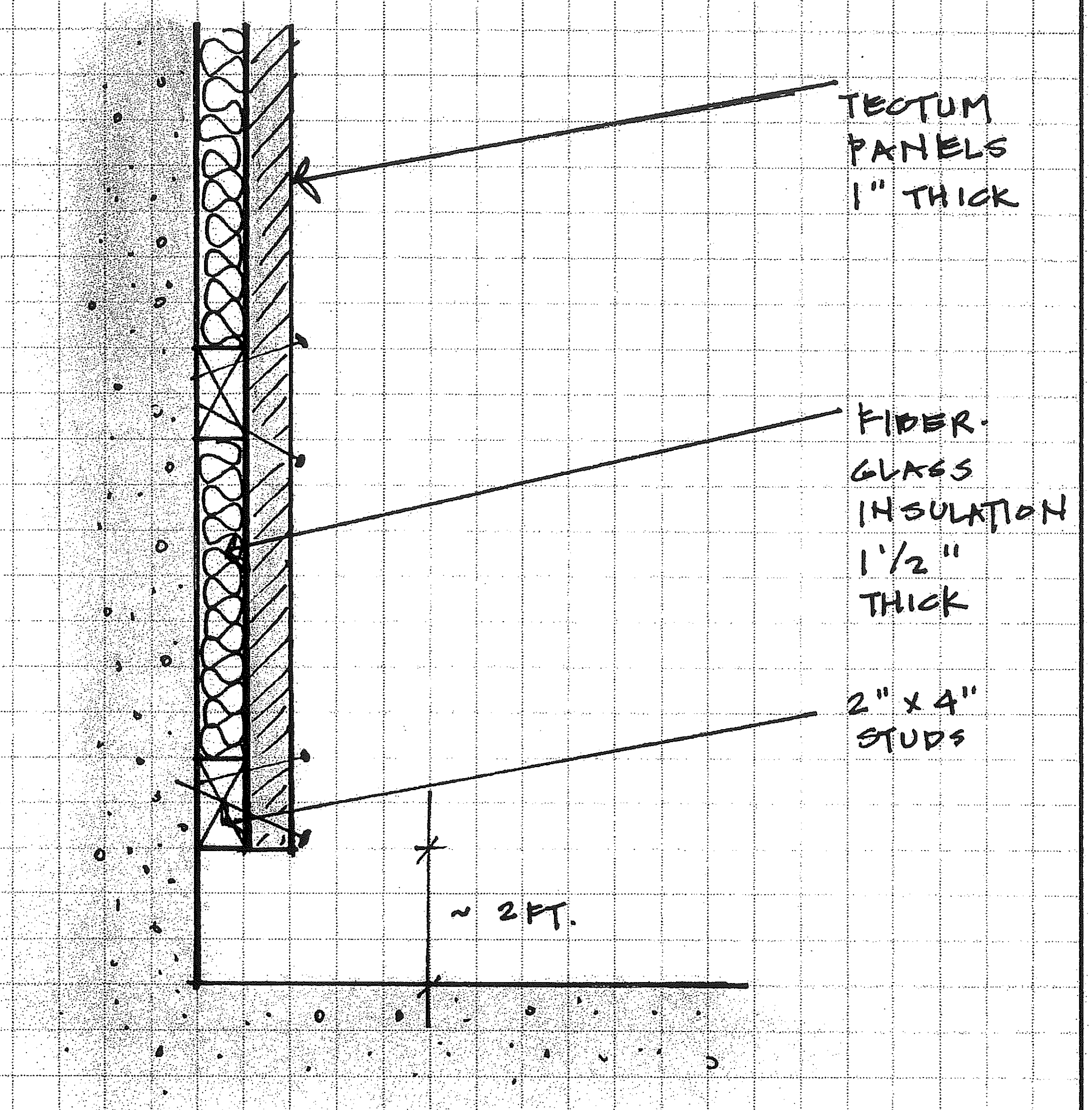

SK. 2 EMERG. GEN. ROOM WALL TREATMENT

MAINE MEDICAL CENTER - CENTRAL UTILITY PLANT

Study Location	**Total without Emergency Generators**	**Total with one Emergency Generator**	**Total with two Emergency Generators**	**Portland Nighttime Limit**	**Portland Daytime Limit**	Emergency Generator 1 Room Intake	Emergency Generator 2 Room Intake	Emergency Generator 1 Discharge	Emergency Generator 2 Discharge	Emergency Generator 1 Exhaust	Emergency Generator 2 Exhaust	Boiler Room Inlet (AHU-1)	Boiler Room Relief Louver	Chiller Room Inlet (AHU-2)	Chiller Room Exhaust	Cooling Tower 1A & 1B	Cooling Tower 2A & 2B	Cooling Tower 3A & 3B	EF-2 Roof Exhaust Fan
1	42	47	55	**55**	**60**	30	31	46	54	25	26	<20	<20	<20	<20	34	38	38	34
2	51	54	55	**55**	**60**	48	47	45	47	36	36	29	35	20	<20	46	47	47	34
3	51	52	53	**55**	**60**	42	42	41	45	34	33	32	31	23	<20	47	46	45	35

Table 2. Estimated sound levels produced by Central Utility Plant mechanical equipment at study locations.

Tab 12

Department of Planning & Development
Lee D. Urban, Director

Division Directors
Mark B. Adelson
Housing & Neighborhood Services

Alexander Q. Jaegerman, AICP
Planning

John N. Lufkin
Economic Development

DATE: July 5, 2004
TO: Rick Seeley, Senior Planner GPCOG
FROM: Wendy Cherubini, HCD Program Mgr.
RE: Maine Medical Center Development Compliance with Housing Replacement Ordinance

Maine Medical Center (MMC) is proposing to demolish two residential structures located at 33 and 37 Crescent Street. According to Marge Schmuckel, Zoning Administrator 33 Crescent Street's legal use is 2 dwelling units and 2 rooming units. 37 Crescent Street's legal use is 5 dwelling units. The total units to be demolished is 9; 7 dwelling units and 2 rooming units. MMC is requesting a contract zone to construct a parking structure and proposes replacing two of the 7 dwelling units with new units and contributing to the Housing Development Fund for the remaining 5 dwelling units and 2 rooming units.

Section 14-483. Preservation and Replacement of Housing Units

f) Approval

f)(1) MMC has filed an application cover letter dated 6/3/04.

f)(2) Tenant List – Not applicable, all units are vacant

f)(3) Not applicable

g) Not applicable

h) Housing Replacement by the Creation of New Units

h)(1) MMC is proposing to convert a formerly residential building located at 325-327 Brackett Street into 2 two bedroom dwelling units.

h)(2) None of the replacement units have previously been on the market as of date of application.

h)(3) 325-327 Brackett Street currently a non-residential building with MMC offices, the property has not been a candidate for site plan approval as of the date of application.

h)(4) 325-327 Brackett Street was previously a two unit building. The units are side to side and in fact the building may at one time have been two separate structures. MMC is proposing to go back to the previous configuration – a unit on each side, each with two floors of living space.

MMC is proposing that each unit will have two bedrooms although one may be converted to three bedrooms because of its size. Once the building is rehabilitated the two replacement units will have better amenities than the units being demolished and at least one will be larger and have two bathrooms.

h)(5) 325-327 Brackett Street is located on the corner of Brackett and Bramhall Streets. This is a corner location with high visibility and creates an entrance to the neighborhood. The structure defines the boundary between MMC and the West End. Built around 1900, the building has some beautiful features. While not located within the Historic District, it is near the West End Historic District which defines the character of the neighborhood's residential buildings. Conversion plans could be subject to historic preservation standards via an administrative review.

h)(6) Development meets requirement under 6)b – conversion of nonresidential building to residential use. While the new units will each have 2-3 bedrooms and be somewhat larger than the units being demolished, the building does not lend itself to being divided into a larger number of smaller apartments. These 2-3 bedroom rental units will meet an existing need in Portland for family housing.

i) Availability of Replacement Housing Units

i(1) Once the plan for the replacement units has been approved, MMC shall provide a performance guarantee in the form of a Letter of Credit which comports with the requirements of sub-section (m) has been posted for the replacement units with the City.

i(2) The two replacement units at 325-327 Brackett Street shall be available for occupancy prior to a certificate of occupancy being issued for the new MMC garage on Crescent Street. In order to ensure that these units remain as housing units, as a condition of the contract zone, MMC shall agree to maintain 325-327 Brackett Street as an occupied 2 unit residential structure for 30 years from the date the Certificate of Occupancy is issued. Should MMC opt to sell the building this condition will carry forward to the subsequent owner.

i(3) The replacement housing shall be ready for occupancy within 18 months from the date on which the Planning Authority's approval was granted. An extension of up to a total of 24 months may be granted provided the replacement units are at least 30% complete.

i(4) In the event the units at 325-327 Brackett Street are not completed within 24 months or the applicant wishes to obtain a certificate of occupancy for the original site prior to the availability of the replacement housing units, the applicant can request that the City draw on the Letter of Credit, pursuant to sub-section (1), to complete the replacement units or deposit such funds in the City's Housing Development Fund.

(j) Housing Replacement by Contribution to the City's Housing Development Fund

j(1)&(2) An applicant may meet the requirements of this section by contributing $50,000 per dwelling unit and $30,000 per rooming unit adjusted annually beginning 1/1/04 as per the Consumer Price Index for Urban Wage Earners and Clerical Workers "CPI-W" to the City's Housing Development Fund. For 2004 the multiplier is 1.018 (180.9/177.7 = 1.018) or $50,900 per dwelling unit and $30,540 per rooming unit.

After accounting for the two new units at 325-327 Brackett Street, MMC intends to demolish 5 dwelling units and 2 rooming units. To meet the requirements of this section MMC is proposing to contribute a total of $315,580 to the Housing Development Fund; (5 x $50,900) + (2 x $30,540). This will meet the requirements of this section.

MMC's replacement plan meets the standards of the Preservation and Replacement of Housing Ordinance provided that prior to a building permit being issued for the new development:

- A change of use permit is obtained for the conversion of 325-327 Brackett Street to 2 residential units;
- A check in the amount of $315,580 has been received by the City and deposited in the Housing Development Fund; and
- Conditions stipulated in i(1), (2), and (3) as noted above are met.

Also Recommended

- Historic Preservation staff complete an administrative review of the planned conversion;

Tab 13

Maine Medical Center
Community Meeting
January 24, 2005
7:00pm, Classroom #7
Dana Center
MMC Bramhall Campus

Mr. Gray, MMC Vice President of Planning, opened the meeting by thanking everyone for attending. This meeting was originally scheduled for January 12, 2005, but was rescheduled due to weather.

The meeting is required by the City of Portland ordinance governing Planning Board review of projects. An attendance sheet was passed around for those who wished to record their attendance (attached). Mr. Gray stated that minutes of the meeting will be prepared and will be included in material that will be sent to the Planning Board for its February 1, 2005 Public Hearing (6:30pm, City Hall). Also in attendance from MMC were Mr. Mike Ryan and Mr. Hank Dunn.

Project Description

Using visual aids, Mr. Gray provided an overview of the five major components of the project:

- four story, 192,000 square foot addition on Charles Street for obstetrical and newborn services
- 512 car parking garage on Congress Street adjacent to the existing garage
- enclosed connector between new parking garage and the main buildings on the campus
- a central heating and cooling plan on Gilman Street
- a helipad on the top of the existing parking garage so that 200-300 flights per year can come directly to MMC rather than to the Jetport

Mr. Gray also commented briefly on improvements to the Vaughan Street parking lot, general landscaping, widening the Gilman Street entrance to the campus for Fire Department vehicles and the replacement of housing removed to construct the parking garage.

Summary of Comments and Questions

Presented below are the comments and questions. MMC's responses are presented in italics in parantheses.

1.) Parking Garage

- location *(best use of site with limited use potential)*
- design, i.e., why can't it look like something else? *(limited alternatives due to ventilation requirements; alternatives being explored)*
- impact on traffic *(overall impact is minimal; will keep traffic from campus by having cars enter the garage on Congress Street)*
- the two garages should be connected *(do not plan to do so due to expense)*
- why do you need another garage? *(demand for spaces exceeds supply)*
- height of garage *(70 feet)*
- why not put on one additional floor and put retail on the street level? *(suggestion noted)*
- are there entrances on Congress Street and Crescent? *(yes)*
- existing garage design is not attractive *(comment noted)*
- visual effect of two parking garages and the "gateway to the City" *(comment noted)*
- change in traffic circulation on to Ellsworth/Wescott instead of Charles Street *(preferred route by City EMS and Fire Department)*

2.) Central Utility Plan location *(best use of a site with minimal other uses)*

3.) Helipad

- location, i.e., not on one of the other buildings? *(best location among options)*
- flight route, i.e., were other routes tested in the fly-over? *(yes, i.e., over Hadlock Field and MMC medical office building)*

4.) Plans for Crescent Street vacant houses? *(sell, along with 8 others to private owners)*

5.) Relationship of MMC project to Mercy Hospital project

  - has Mercy received its State approvals? *(no)*
  - why can't the MMC project be built on the Mercy site? *(Mercy does not provide these services, i.e., neonatal intensive care)*

6.) Impact of new buildings and re-use of buildings on staffing, traffic and parking *(minimal impact, patient volume at MMC not expected to grow substantially; some additional staff with re-use of building)*

7.) Tax impact of the project *(net add of $27,000 in taxes)*

8.) Were shadow studies conducted? *(yes, existing buildings create shadows; new buildings do not add to that)*

9.) Involvement of the community in planning *(12 meetings with representatives of Parkside, Western Prom and Valley/Gilman neighborhoods)*

- had not heard about this before…seems late in the process
- notices of prior meetings

10.) Does MMC have its State certificate of need approval for the project? *(yes)*

Written comments submitted at the meeting by Raina Rippel are attached.

Respectfully Submitted,

Paul D. Gray
Vice President of Planning
Maine Medical Center

MAINE MEDICAL CENTER
COMMUNITY MEETING
JANUARY 24, 2005
7 PM, DANA CENTER #7
BRAMHALL CAMPUS

NAME	ADDRESS
Jon Bell	114 Noyes ST Portland
Chris Busby	11 Cushman St. Portland
Catherine Whittemore	211 Vaughan St #5
FREDERICK AMEY	199 VAUGHAN #5, PORTLAND
Marie Gray	263 State St. Portland
Iwani Awlari	34 Gilman St.
Tom Santarelli	282 Spring St, Portland
DAVE GARRITY	174 Danforth St
EDWARD HOBLER	174 DANFORTH St.
Chris Hirsch	6 Houlton St
Rebeccah Schaffner	184 Clark St.
Raina Rippel	24 Forest Street
CURTIS Sloan	217 Marshall Ave.
Hank Dunn	MMC
Robert C. Hains	250 Holm Ave. (Property Taylor + May Streets)
PAUL STEVENS	21 THOMAS ST.
Peter Murray	89 West St
Debby Murray	89 West St.
Dodd STEVENS	21 THOMAS ST
A MAINS MONAGHAN	47 MITTON ST
Jo Coyne	36 Salem St.

MMC Comments 1/24/05

Raina Rippel, resident, 24 Forest Street

I want to clarify that I am not speaking tonight on behalf of the Neighborhood Advisory Council, but rather as a neighbor of MMC. I was invited by the Parkside Neighborhood Association to be a representative of the Assoc. on the Neighborhood Advisory Council to this project. In that role, I did not feel entirely free to share my own opinion, either professionally or personally. I'd like to take five minutes to do that tonight, focusing primarily on the proposed parking garage.

I often feel like Cassandra in seeing the plans put forth both locally and nationally, and in this case, I am particularly concerned about this construction. Traffic problems I think have been **seriously** underestimated. I understand that anecdotal evidence will almost certainly be discounted, and I've seen this happen already in the process of these meetings. However, my anecdotal evidence comes from that of a frequent bicyclist and pedestrian year-round in this neighborhood, and as such I have spent much time observing traffic flow in particular on Congress Street.

I am not in a position to have numbers to back me up, but I think inevitably the addition of parking garage entry and exit traffic onto this stretch of Congress Street will create a bottleneck. People trying to get into the garage will significantly impede the flow of traffic up the hill, and people exiting the garage I think will find it very difficult on many occasions to easily do so.

Knowing that people **will** illegally turn left from the garage exit, I would anticipate that accidents may very well take place here as well, given the speed and the curve present at this point in the street. I would strongly encourage MMC to take into account the distinct possibility that another exit from the garage might be necessary and preferable.

On an emotional level, I am sad to see this happen to our neighborhood, as I think, regardless of any concessions MMC may make on the parking garage design or neighborhood trails, this can only be a detraction from the general feel of this area, given the overwhelming presence of a veritable tunnel of parking garage structures.

I sense that only cosmetic dressing will be offered to the neighborhood, and I would again encourage MMC to fully understand and compensate this neighborhood, especially the local businesses and residents, for the negative impact that will happen. A creative and helpful attitude would go a long way towards mitigating MMC's negative presence in the area.

Or, better yet, put the parking garage somewhere else!

Living in the shadow of MMC, it's easy to feel like David vs. Goliath. Our neighborhood council meetings have primarily been concerned with the problems associated with the helipad. I can't say that I was ever vehemently against the helipad, although I know what a burden it will be on our location in particular, but I have to express myself more clearly on the parking garage. I think MMC should clearly understand that the neighborhood directly in their shadow is perhaps more sympathetic to their needs in this case, but we are bound to be less vocal than other neighborhoods given our make-up of working class, renters and lower income residents. However many home owners do live in this area, and whether renting or more permanently settled, I know many of us take pride in living here.

Professionally, I just have one last thing to add. Although I'm not speaking tonight on behalf of PSR/Maine, my job as director of the Maine Chapter of Physicians for Social Responsibility puts me in the unique position of seeing health care from a broader perspective than is often taken by medical establishments such as MMC. It concerns me greatly that, given our poor air quality, the onset of climate change, and the asthma and obesity epidemic facing Maine, MMC would choose to dedicate their health care resources to the building of a large parking garage, decreasing the possibility that people will get fresh air and exercise in association with their visit to the hospital. **We too often believe that the car is the only answer to transportation needs, and this is particularly detrimental to public health on a variety of levels.** MMC can perhaps be expected not to view this project in terms of long-term public health concerns, but I am not sure they can be excused for such short-sightedness.

In conclusion, although I recognize the perceived necessity for this construction project, I would not endorse the parking garage in particular, and as a neighbor, I am sorry to see this go forward. Thank you.

Tab 14

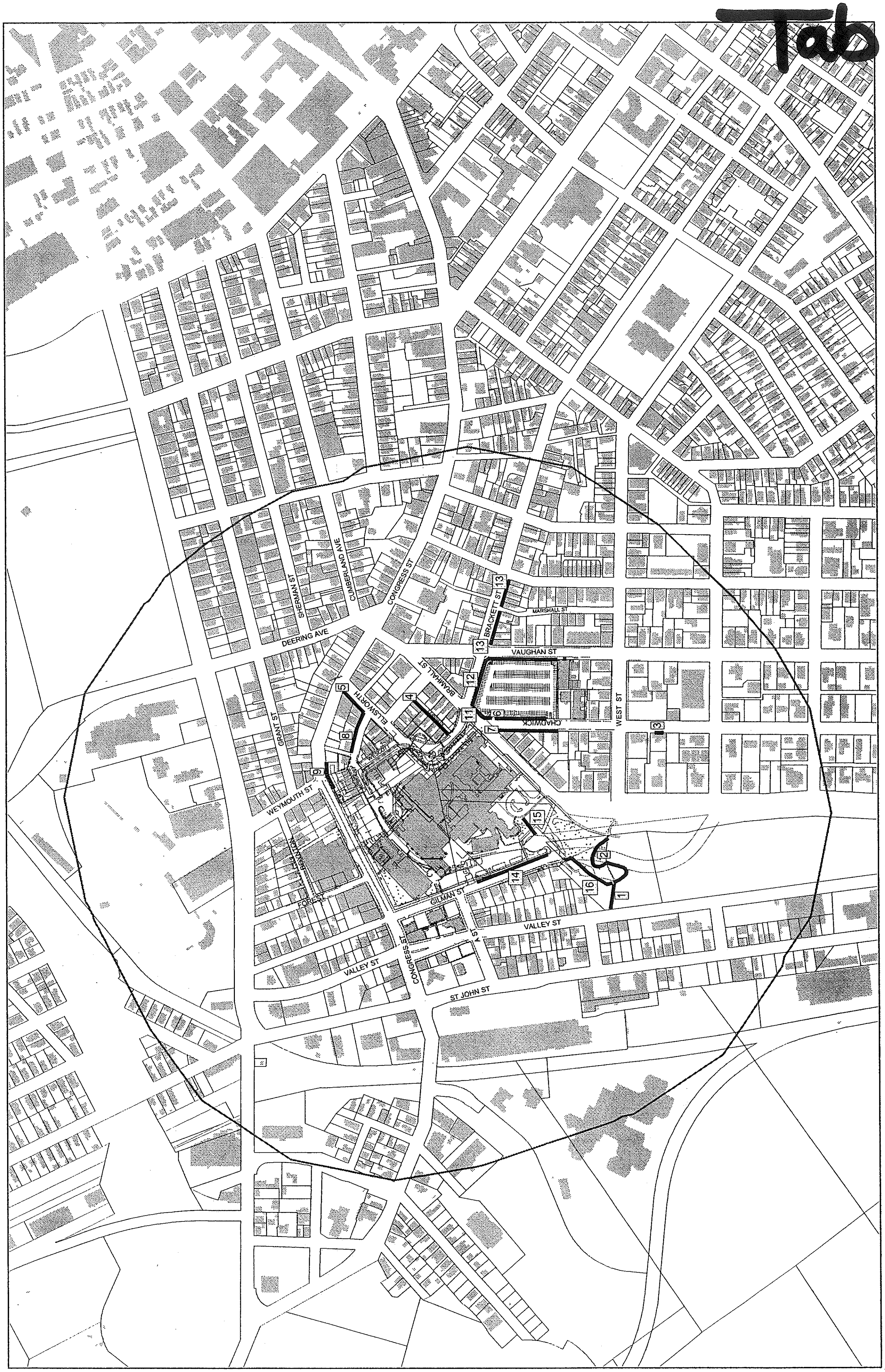
SHERMAN ST
CUMBERLAND AVE
CONGRESS ST
DEERING AVE
BRACKETT ST
MARSHALL ST
VAUGHAN ST
BRAMHALL ST
ELLSWORTH
GRANT ST
CHADWICK
WEST ST
WEYMOUTH ST
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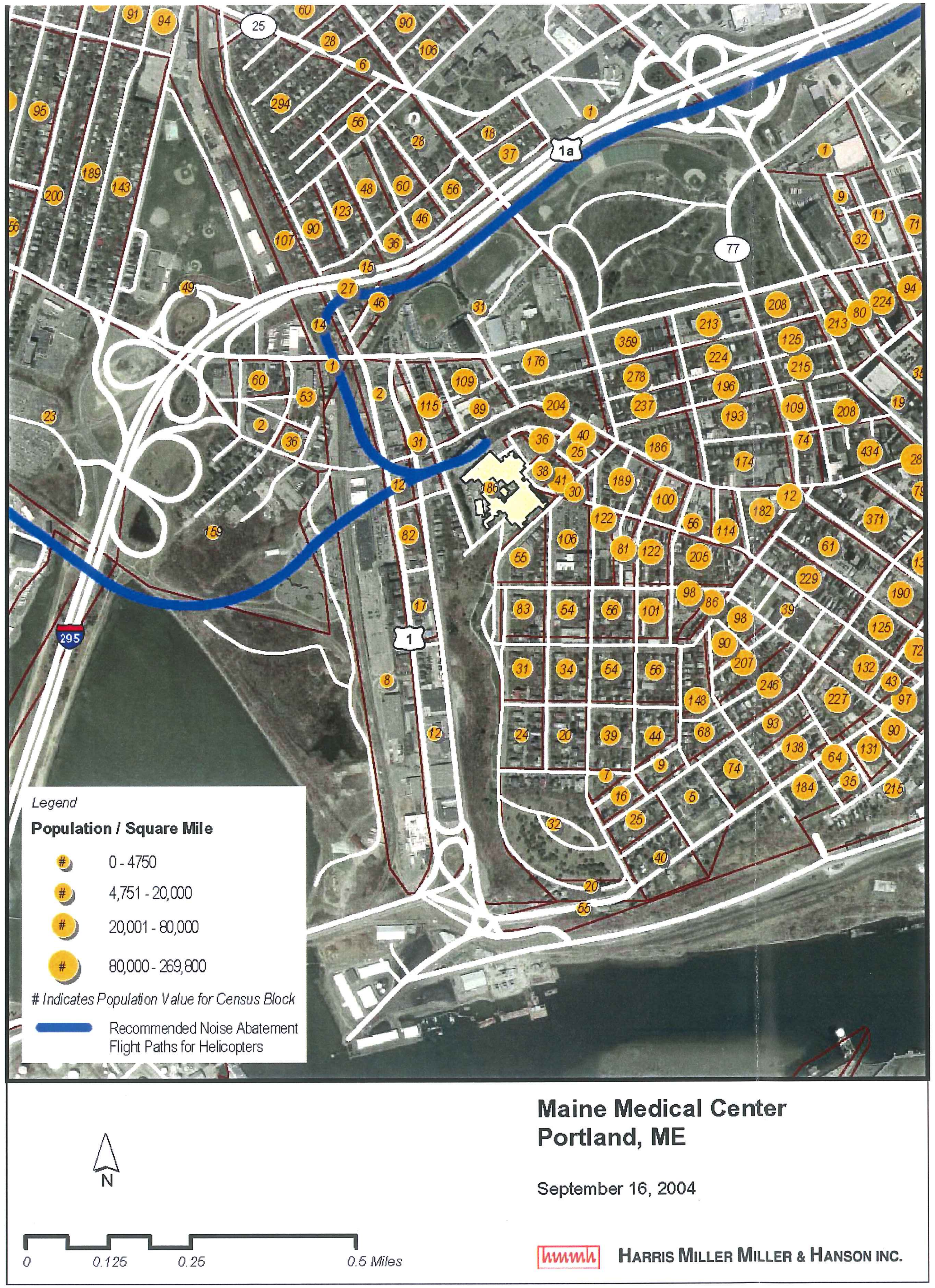
EXHIBIT D, PAGE 1
FLIGHT PATHS



Maine Medical Center
Portland, ME

September 16, 2004

hmmh HARRIS MILLER MILLER & HANSON INC.

Tab 7

HARRIS MILLER MILLER & HANSON INC.
15 New England Executive Park
Burlington, MA 01803
Tel. (781) 229-0707
Fax (781) 229-7939

MEMORANDUM

To: Alex Jaegerman, Sarah Hopkins
Department of Planning and Development
City of Portland, Maine

From: Robert L. Miller

Subject: Review of RSE Noise Studies for MMC's Proposed Helipad

Date: 22 July 2004

At the request of the City of Portland's Department of Planning and Development, HMMH has been asked to attend a site visit and review noise analyses conducted by Resource Systems Engineering (RSE) pertaining to noise impacts and mitigation measures associated with helicopter operations to and from the Maine Medical Center's proposed helipad. The site is to be located towards the northern corner of MMC's existing parking garage that borders on Congress Street, and will be elevated several feet above the uppermost floor of the garage. The comments that follow with regard to the proposed facility are in no way intended to counter or negate the medical benefits derived from the helipad. On the contrary, this memo assumes the helipad will be constructed and operated substantially as described in RSE's 15 April 2004 report entitled "Community and LifeFlight Helicopter Sound Level Study" and its 1 July 2004 successor report entitled "Proposed Helicopter Pad Noise Mitigation". The purpose of this memorandum is to review the findings of these reports and comment in particular on mitigation measures that could be considered for implementation by inclusion in the MMC Contract Zone Agreement.

It is my understanding that community members have also suggested a full independent study of the noise from the helipad be conducted, including additional measurements and analysis of impacts as well as mitigation. In my opinion that additional effort is unnecessary. My review of the work conducted by RSE in support of the proposed project is that it was conducted professionally, that the instrumentation used to collect the noise data was of high quality, that the two reports cited above are written clearly, are open and forthright in their analyses and reporting of data, and that the work summarized within each document appears to have been carefully accomplished and with no material error. I have also compared RSE's measurements at site CP-5 (Bowdoin and Chadwick Street) with data that HMMH collected at two relatively nearby locations, 75 Vaughn Street and 55 Bowdoin Street, made in connection with work conducted for the City on a noise compatibility study at Portland International Jetport and found them to reflect substantially similar conditions. Finally, I supplemented my review of the RSE reports with at least two substantive phone conversations with Scott Bodwell, the principal investigator for RSE, who has been very helpful in elaborating on his work and answering each of my questions. My criticisms to the extent they exist are directed at the interpretation of the noise levels as reported, not at the accuracy of the findings.

With regard to noise impacts:

- Page 3 of the 15 April report, the 'Sound Level Study', indicates that the hourly Equivalent Sound Level (L_{Aeq}) "is the parameter specified for use by the Maine DEP and FAA for establishing pre-development ambient sound levels." In lay terms, the L_{Aeq} may be thought of as the average sound level over a one-hour period. Table 1 on page 4 summarizes the average Equivalent Sound Levels measured during daytime and nighttime hours at six community locations near the MMC. Typical daytime levels ranged from 56 to 61 dBA; nighttime levels slightly less at 54 to 57 dBA. These levels appear to have been measured accurately and are typical of quiet urban areas, and I have no reason to doubt their validity. Many aviation noise studies compile similar hourly or longer-term Equivalent Sound Level measurement data to characterize existing background noise.

Two pages later, however, Table 2 of the Sound Level Study draws comparisons of sound levels caused by four helicopter flight tests, *not to the ambient hourly* L_{Aeq}*'s of Table 1, but to background levels represented by the four loudest 5-second* L_{Aeq}*'s.* These short-duration "ambient" levels are typically caused by individual vehicles on the local street or by jets operating in or out of Portland International Jetport, but they are *not* representative of the average sound level over the full hour during which the measurements were made. The 5-second ambient levels range from 69 to 83 dBA at the six community sites mentioned above, on the order of 15 to 20 decibels higher in value than their hourly counterparts in Table 1, which RSE had indicated earlier was the appropriate length of time used by FAA and Maine DEP to characterize ambient. Measurements of helicopters, which are reported in Table 2 to be as much as 8 to 10 decibels above the highest non-helicopter events, are actually 22 to 27 decibels above the hourly L_{Aeq}'s. In addition, some of the helicopter events of Table 2 that are reported to be as low as 17 dB less than the four loudest "ambient" (non-helicopter) events, are in fact 15 to 18 dB higher in level than the ambient as represented by the hourly values. An alternative to RES's Table 2, comparing helicopter events to the hourly values of ambient noise, is shown below.

Table 2 (Revised)

Comparison of Helicopter Flight Test Sound Levels with Ambient Levels in the Community

Position	Average 5-Second Equivalent Sound Levels of Helicopter	Average Hourly Equivalent Sound Levels of Ambient Daytime (7am - 9pm)	Average Hourly Equivalent Sound Levels of Ambient Nighttime (9pm - 7am)	Sound Level Differences Daytime (7am - 9pm)	Sound Level Differences Nighttime (9pm - 7am)
CP-1	82	59	57	23	25
CP-2	88	61	57	27	31
CP-3	80	56	54	24	26
CP-4	79	56	55	23	24
CP-5	66	51	48	15	18
CP-6	71	56	56	15	15
CP-7	71	not meaasured		n/a	
CP-8	63	not meaasured		n/a	
CP-9	65	not meaasured		n/a	

The appropriate conclusion from this comparison as well as from the data in the original Table 2 is that helicopter operations 15 to 30 dB above the background noise, though occurring only occasionally, will be very noticeable to the residents in those neighborhoods, especially at sites CP-1 through CP-4 where the operations are expected to be on the order of 3 dB to as much as 8 to 10 dB higher than even the loudest events occurring at those sites now. A helicopter flight that is 8 to 10 dB higher than other individually identifiable noise *sources in the neighborhood would typically be judged to be about twice as loud as those other sources.*

- *The helicopter sound levels at sites CP-1 through CP-7 are also high enough to cause speech interference outdoors* – a minor effect at the Bowdoin and Chadwick location (CP-5), but significant during operations near CP-1 through CP-4. *With open windows, helicopter sound levels at CP-1 through CP-4 are also likely to cause speech interference indoors.*

- *Sound levels are high enough to cause sleep disturbance in the vicinity of site CP-2 where measured 5-second sound levels were highest.* At a frequency of 5 to 6 flights per week and an estimated 13 to 30 percent of the flights occurring at night (page 2 of the Mitigation Report; each flight representing a landing and a takeoff), it is estimated that there will be a night flight about once every 5 to 10 days. Again, not particularly frequent, but worthy of consideration for mitigation.

With regard to mitigation:

- Flight paths flown during testing approximated routes that appeared beneficial for noise abatement, generally because they follow major transportation corridors. A figure attached to this memorandum plots the population densities and numbers of people per census block in the vicinity of the MMC, suggesting refinements to the flight corridors that could be used to minimize overflights of people. *Optimum routes to and from the northeast, northwest, west, southwest, and east are shown in blue in the figure and are recommended for use whenever patient condition and weather permit. Under non-emergency conditions, the preferred route for helicopters approaching or leaving the helipad is to enter or exit the area from or to the southwest, crossing the Fore River just east of the Interstate 295 bridge. FAA Air Traffic Control personnel should review these routes before formally including them the Contract Zone Agreement.*

- RSE's Mitigation Report (page 4) indicates that pilots should maintain as high an altitude as possible on approach, descending at 12 to 15 degrees when making their final approach to the pad. Ideally, *pilots should maintain level flight at or above 1,000 feet MSL except when climbing or descending to the helipad within approximately one mile from the MMC.*

- Table 3 of RSE's Mitigation Report compares noise levels at six residential locations for a helicopter facing north on the helipad with one facing south. Results indicate a significant improvement in noise for the helicopter facing to the north. Reductions of 3 decibels should be noticeable, while improvements of 6 to 10 decibels are generally viewed as a halving of the noise. These largest improvements are expected to occur at RH-1 immediately east of the proposed new garage, and at RH-4 across Congress Street from the existing parking garage. It is not clear how a LifeFlight pilot will maneuver his/her helicopter to take advantage of the apparent benefit but it is suggested that *the Contract Zone Agreement should include wording to the effect that "patient condition and weather permitting, a pilot using the MMC helipad will maneuver his/her helicopter so that is oriented on the pad on a northerly heading of 360 degrees whenever possible."*

- Tables 4 and 5 of the Mitigation Report show the benefits of two barrier alternatives in combination with the north- or south-facing orientation of the helicopter on the pad. The first alternative (Case 003) employs a combination of vertical and sloped barriers; the second (Case 004) involves only the sloped barriers. *From the City's perspective, the most preferable scenario assessed in the RES report on mitigation is Case 003 in combination with the northerly orientation of the helicopter. Of all alternatives presented, it results in the lowest sound levels at receiver locations RH-2 through RH-5 and generally benefits the largest number of nearby residents.*

- If conditions were to preclude construction of Case 003, Case 004 also provides important improvements that RSE tends to discount. Reductions in noise of 3 to 8 decibels at sites RH-3, RH-4 and RH-5 would all be noticeable, especially in the vicinity of RH-5; yet RSE states on page 14 that the sloped barriers provide no significant additional noise reduction…" beyond that achievable through orientation of the helicopter on the pad. We disagree. *The sound level reductions afforded by sloped barriers in combination with the northerly orientation of the helicopter on the pad are still sufficiently large to be considered beneficial, and they also provide noticeable noise reduction if the helicopter is positioned in a southerly orientation.*

MAINE MEDICAL CENTER
PORTLAND, MAINE

COMMUNITY AND LIFEFLIGHT HELICOPTER SOUND LEVEL STUDY

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35 Church Road, P.O. Box K
Brunswick, Maine 04011-0835
Telephone (207) 725-7896 / Fax (207) 729-6245
E-Mail rse@gwi.net
www.resourcesystemsengineering.com

Project No. 010120

APRIL 15, 2004

ACKNOWLEDGMENTS

Resource Systems Engineering wishes to thank personnel at Maine Medical Center and LifeFlight of Maine for their assistance and cooperation during conduct of the helicopter flight testing.

Resource Systems Engineering personnel responsible for this investigation and report are Charles F. Wallace, Jr., P.E., R. Scott Bodwell, P.E., Ann M. Vedock, Environmental/Acoustical Specialist and Ronald H. Mattson, CAD Technician/Acoustical Specialist.

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DISCLAIMER

MAINE MEDICAL CENTER
COMMUNITY AND LIFEFLIGHT HELICOPTER
SOUND LEVEL STUDY

CONTENTS

TABLES

FIGURES

MAINE MEDICAL CENTER
COMMUNITY AND LIFEFLIGHT HELICOPTER
SOUND LEVEL STUDY

1.0 INTRODUCTION

On Saturday, September 13, 2003, helicopter flights were conducted at Maine Medical Center to simulate future operation of the proposed helipad operation. The helicopter was flown by LifeFlight of Maine, who currently provides emergency medical helicopter transport to Eastern Maine Medical Center in Bangor and Central Maine Medical Center in Lewiston.

The objective of the flight testing was to compare helicopter sound levels with existing community and hospital sound levels. Previously, RSE had monitored community sound levels in the vicinity of the hospital for a 24-hour period covering December 18-19, 2002. During this period, monitoring was conducted at six community positions (CP-1 through CP-6). Three more community positions and four hospital positions were added for monitoring during the helicopter flight test. Sound levels at all hospital and community positions were measured before, during and after the helicopter flight test.

LifeFlight operates two Agusta 109C helicopters in Maine: one based in Bangor and one based in Lewiston. The Agusta 109C is expected to be the primary helicopter using the proposed helipad at MMC. Flight testing with an Agusta 109C was planned for the simulation; however, the helicopter was called to an emergency and was not available. In order to maintain the community schedule, a BK 117 backup helicopter was flown instead.

This report compares sound levels measured during flight tests with ambient community sound levels without the helicopter. The objective of this report is to compare measurement results of the helicopter flight test with existing ambient sound levels. The report does not include noise model predictions of future sound levels reflecting full build-out conditions or provide a comparison to local, state and federal noise standards.

2.0 MONITORING POSITIONS

During the flight test, monitoring was conducted at nine community positions and four hospital positions. Community monitoring positions were selected based on the results of area mapping, ownership and accessibility, and potential noise impacts from the helipad. Community mapping included identification of land uses and zoning in the vicinity of the Maine Medical Center.

The resulting vicinity site plan (Figure 1) provides a noise study map that delineates community monitoring positions in relation to structures and property boundaries of Maine Medical Center, structures and lot lines of property in the vicinity of MMC, existing land use and zoning designations, and the location of the proposed helipad and approach/departure routes.

The nine community monitoring positions are as follows:

CP-1	Gilman and A Street - West of MMC
CP-2	Congress and Weymouth Street - North of MMC
CP-3	Crescent and Wescott Street - Northeast of MMC
CP-4	Ellsworth and Charles Street Ext - East of MMC
CP-5	Bowdoin and Chadwick Street – South of MMC
CP-6	West Prom and West Street – South of MMC
CP-7	Grant Street (Parkside) – Northeast of MMC
CP-8	Neal Street – Southeast of MMC
CP-9	Brackett and Carleton Street – East of MMC

Hospital positions include three inside the hospital and one outside on a nearby rooftop. The interior positions were selected in conjunction with Maine Medical Center to represent areas of the hospital known to be sensitive to noise intrusion. The exterior position was selected for purposes of determining the transmission loss across the exterior walls of the hospital. The hospital positions are as follows:

MC-3E	Outside on the rooftop of the Lower Bean Building
MC-3I	Inside the NICU (Bean Building)
MC-5I	Inside the Newborn Nursery (Richards Tower)
MC-6I	Inside the Teen Room (Barbara Bush Hospital)

The hospital locations are shown on Figure 2 along with some of the closest community monitoring positions.

During the flight test monitoring, RSE personnel were stationed at community positions CP-3 (Crescent) and CP-6 (West Prom), and hospital positions MC-3I (NICU) and MC-5I (Nursery). RSE personnel recorded observations prior to, during, and after the flight testing.

3.0 NOISE STANDARDS

A review of federal, state and local noise standards indicates there is no specific noise standard that Maine Medical Center is required to meet during operation of the proposed helipad. The pertinent federal regulation is a voluntary guideline, the Maine DEP regulation exempts aircraft operation, and the Portland Code does not appear to regulate noise from uses in the R-6 zone. A brief summary of local, state and federal noise standards and their potential applicability to the proposed helipad can be found in Appendix I.

4.0 EXISTING COMMUNITY SOUND LEVELS

On December 18 and 19, 2002, sound levels in the vicinity of the proposed helipad were monitored for a 24-hour period to determine existing ambient sound levels. RSE monitored ambient sound levels at six monitoring positions CP-1 through CP-6 as shown on Figure 1, Vicinity Site Plan.

Instrumentation consisted of Larson-Davis Model 812 Integrating Sound Level Meters, which were programmed to continuously measure sound levels and calculate statistics at both hourly and one-second intervals. One Larson-Davis Model 824 Sound Level Meter and Real Time Analyzer was used to measure sound levels at position CP-3. It was programmed to continuously measure sound levels, including one-third octave band readings, and calculate statistics at both hourly and five-second intervals.

The sound level meters meet Type 1 (precision) performance requirements of American National Standard Institute Specification for Sound Level Meters, ANSI S1.4-1983. The microphones were fitted with standard windscreens and mounted on tripods at a height of four to five feet above the ground. The sound level meters were calibrated before and after the twenty-four hour monitoring period using a Bruel & Kjaer 4231 Sound Level Calibrator. Additionally, a certified laboratory performs a calibration within 12 months of the measurements. Calibration certificates are available upon request.

During monitoring on December 18-19, 2002, temperatures ranged from 19 to 42 degrees F; winds were generally from the northwest ranging from 3 to 8 mph during the day and 0 to 3 mph at night. Skies were clear.

Hourly sound level readings, including L_{Aeq}, L_{AFmax}, L_{Amin}, L_{A1}, L_{A10}, L_{A50} and L_{A90} values, are presented in Appendix II as Tables II-1 through II-6 and Figures II-1 through II-6. The L_{Aeq} represents the average energy level of all sounds present during the measurement period. The one-hour or hourly L_{Aeq} is the parameter specified for use by the Maine DEP and FAA for establishing pre-development ambient sound levels. The L_{AFmax} is the maximum A-weighted sound level, using fast time weighting, and L_{Amin} is the minimum A-weighted sound level during the hour. L_{A1} is the sound level exceeded 1% of time. Likewise, L_{A10}, L_{A50} and L_{A90} are the sound levels exceeded 10%, 50% and 90% of the time during the hour.

At CP-1, during Maine DEP daytime hours (7 am to 7 pm), hourly L_{Aeq} readings ranged from 58 to 63 dBA with an average of 60 dBA. During Maine DEP nighttime hours (7 pm to 7 am), hourly L_{Aeq} readings ranged from 54 to 62 dBA with an average of 57 dBA.

At CP-2, during Maine DEP daytime hours, hourly L_{Aeq} readings ranged from 59 to 65 dBA with an average of 61 dBA. During nighttime hours, hourly L_{Aeq} readings ranged from 55 to 61 dBA with an average of 57 dBA.

At CP-3, hourly L_{Aeq} readings during Maine DEP daytime hours ranged from 53 to 59 dBA with an average of 57 dBA. Hourly L_{Aeq} readings during nighttime hours ranged from 51 to 58 dBA with an average of 54 dBA.

At CP-4, hourly L_{Aeq} readings during Maine DEP daytime hours ranged from 55 to 59 dBA with an average of 57 dBA. Hourly L_{Aeq} readings during nighttime hours ranged from 53 to 59 dBA with an average of 55 dBA.

The primary noise sources at CP-1 through CP-4 during daytime and nighttime hours were local traffic and traffic on Interstate 295. Additional sources included aircraft traveling to and from the Portland International Jetport, HVAC equipment at MMC, and residential activity.

At CP-5, during Maine DEP daytime hours (7 am to 7 pm), hourly L_{Aeq} readings ranged from 46 to 58 dBA with an average of 52 dBA. During nighttime hours (7 pm to 7 am), hourly L_{Aeq} readings ranged from 43 to 57 dBA with an average of 48 dBA. Between 7 am and 3 pm, propane heaters operated on the property of CP-5 raising sound levels above typical levels for these hours. The average daytime hourly L_{Aeq} without the heaters operating was 47 dBA from 3 pm to 7 pm. Other noise sources at CP-5 included local and distant traffic, Jetport aircraft, train station, hospital and residential activity.

At CP-6, during Maine DEP daytime hours (7 am to 7 pm), hourly L_{Aeq} readings ranged from 53 to 60 dBA with an average of 57 dBA. During nighttime hours, hourly L_{Aeq} readings ranged from 51 to 65 dBA with an average of 55 dBA. The primary noise sources at CP-6 were local traffic on West Promenade Street and traffic on I-295 to the west. Other noise sources included Jetport aircraft, park/pedestrian and residential activity.

Other calculated values in Tables II-1 through II-6 (Appendix II) are the FAA daytime L_{Aeq} (7 am to 10 pm), nighttime L_{Aeq} (10 pm to 7 am), and day-night (24-hour) sound level (L_{dn}). The L_{dn} values ranged from 56 to 65 dBA. When calculating the L_{dn}, 10 dBA is added to nighttime hourly sound levels. A summary of existing daytime and nighttime sound levels is presented in Table 1. This includes daytime and nighttime sound levels as defined by the Maine DEP and City of Portland, and FAA L_{dn} sound levels.

TABLE 1

Existing Daytime and Nighttime Sound Levels

	Maine DEP Average L_{Aeq}		**City of Portland Average L_{Aeq}**		
Monitoring Position	**Daytime 7 am to 7 pm**	**Nighttime 7 pm to 7 am**	**Daytime 7 am to 9 pm**	**Nighttime 9 pm to 7 am**	**FAA Day-Night Sound Level (L_{dn})**
CP-1: Gilman & A Street	60	57	59	57	64
CP-2: Congress & Weymouth Street	61	57	61	57	65
CP-3: Wescott & Crescent Street	57	54	56	54	61
CP-4: Ellsworth & Charles Street Ext.	57	55	56	55	62
CP-5: Bowdoin & Chadwick Street	52	48	51	48	56
CP-6: West Promenade & West Street	57	55	56	56	63

5.0 HELICOPTER FLIGHT TEST SOUND LEVELS

The flight test and associated sound level testing in the community and at the hospital was successfully completed as a result of extensive planning and coordination between Maine Medical Center, LifeFlight of Maine, and RSE. Flight testing consisted of four separate approach, hover, and departure sequences to simulate planned flight operations associated with the new helipad. The flight path, angle of descent, hover, and departure route flown during each simulation were intended to follow the proposed flight paths to and from the helipad.

Original plans were to fly an Agusta 109C during the flight test. LifeFlight currently stations an Agusta 109C at both Central Maine Medical Center in Lewiston and Eastern Maine Medical Center in Bangor. RSE understands that the Agusta 109C will be used for over 90% of the flights involving Maine Medical Center. During the scheduled flight testing, one of the Agusta helicopters was grounded for scheduled maintenance and the other was called to a medical emergency in Caribou. The backup aircraft is a BK 117, which was substituted for the Agusta 109C for the flight test. RSE understands that the BK 117 is a heavier helicopter with larger engines. Available noise performance data for the BK 117 and Agusta 109C indicates that the BK 117 is slightly louder by 0.6 dBA.

The position of the helicopter was tracked using a portable GPS with time-based horizontal and vertical tracking. Of the four flight test simulations, GPS data was tracked on the first three. Other than coordinates announced by the crew, there was no GPS data tracking during the fourth flight test. Slight variations in the flight path could lead to significant sound level differences at certain positions.

Instrumentation consisted of Larson-Davis Model 812 Integrating Sound Level Meters, which were programmed to continuously measure sound levels and calculate statistics at both hourly and one-second intervals. Two Larson-Davis Model 824 Sound Level Meters/Real Time Analyzers were used to measure sound levels at position CP-3 and MC-3E. These were programmed to continuously measure sound levels, including one-third octave-band readings, and calculate statistics at both one-second and hourly intervals. In addition, a CEL 593 Sound Level Analyzer was used to measure sound levels at position MC-3I to measure one-third octave band sound levels at five-second intervals.

The sound level meters meet Type 1 (precision) performance requirements of ANSI S1.4-1983, Specification for Sound Level Meters. The microphones were fitted with standard windscreens and mounted on tripods at a height of four to five feet above the ground. The sound level meters were calibrated before and after flight test monitoring using a Bruel & Kjaer 4231 Sound Level Calibrator. Calibration certificates are available upon request.

During flight testing, RSE stationed observers inside the hospital in the NICU and the newborn nursery. Community observers were stationed at CP-3 (Crescent Street) and CP-6 (West Prom). The observer at CP-6 had to move to new position CP-7 (Parkside) due to someone tampering with the instrumentation.

Meteorological data, including wind speed and direction, temperature, and relative humidity, was recorded on the Upper Bean Rooftop. During monitoring on September 13, 2003, temperatures ranged from 63 to 69 degrees F and relative humidity ranged from 63 to 83%. Skies were partly cloudy and winds were approximately 5 to 8 mph from 15:00 to 18:00, calming to 3 to 6 mph during the 18:00 hour. Wind direction was primarily from the south and south-southwest.

Monitoring results of the flight tests have been graphed at intervals of five seconds and one minute in order to compare helicopter and existing sound levels at community and hospital positions.

These graphs are presented as Figure Sets 1 through 4 as follows:

Figure Set 1	Community Monitoring Positions: 5-Second Results	Graphs comparing flight test and community sound levels on a 5-second L_{Aeq} basis. Community sound level readings are from 2003 and 2002.
Figure Set 2	Community Monitoring Positions: One-Minute Results	Same as Figure Set 1 but comparing sound levels on a one-minute L_{Aeq} basis.
Figure Set 3	MMC Monitoring Positions: 5-Second Results	Graphs comparing flight test and hospital sound levels on a 5-second L_{Aeq} basis. Hospital sound levels are from 2003 at both indoor and outdoor positions.
Figure Set 4	MMC Monitoring Positions: One-Minute Results	Same as Figure Set 3 but comparing flight test and hospital sound levels on a one-minute L_{Aeq} basis.

Summary result tables were prepared based on review of sound level readings from these Figure Sets. Many comparisons could be made to quantify the differences between ambient (non-helicopter) sound levels and sound levels measured during the flight testing. Considering that each of the four flight tests was a distinct and relatively short-term event, RSE chose to compare the four flight test events with the four loudest non-helicopter community events on both a five-second and one-minute basis. This same approach was used to compare hospital sound levels both outside on the Lower Bean Roof and indoor positions. The following Tables 2 through 5 provide the sound level range and average at each position during ambient (non-helicopter) and helicopter flight test events.

Table 2

Comparison of Ambient Community and Flight Test Sound Levels

5-Second L_{Aeq} (4 Loudest Events)

Position	Ambient Range (2003)	Ambient Average (2003)	Flight Test Range	Flight Test Average	Sound Level Change between Averages
CP-1	76 to 83	79	78 to 89	82	+3
CP-2	71 to 85	79	76 to 93	88	+8
CP-3	69 to 73	71	79 to 82	80	+9
CP-4	66 to 72	69	73 to 82	79	+10
CP-5	77 to 88	83	61 to 70	66	-17
CP-6	73 to 79	75	68 to 76	71	-4
CP-7	66 to 69	68	66 to 75	71	+3
CP-8	74 to 81	78	60 to 65	63	-15
CP-9	73 to 76	74	60 to 68	65	-11

Table 3
Comparison of Ambient Community and Flight Test Sound Levels
One-Minute L_{Aeq} (4 Loudest Events)

Position	Ambient Range (2003)	Ambient Average (2003)	Flight Test Range	Flight Test Average	Sound Level Change between Averages
CP-1	69 to 71	70	72 to 82	75	+5
CP-2	64 to 76	70	73 to 86	82	+12
CP-3	62 to 66	64	75 to 76	75	+11
CP-4	60 to 65	63	67 to 76	73	+10
CP-5	68 to 79	74	55 to 63	60	-14
CP-6	66 to 71	68	62 to 70	66	-2
CP-7	59 to 62	60	62 to 69	66	+6
CP-8	65 to 74	70	54 to 59	57	-13
CP-9	63 to 67	65	57 to 60	59	-6

Table 4
Comparison of Ambient Hospital and Flight Test Sound Levels
5-Second L_{Aeq} (4 Loudest Events)

Position	Ambient Range	Ambient Average	Flight Test Range	Flight Test Average	Sound Level Change between Averages
MC-3E	63 to 66	65	86 to 91	89	+24
MC-3I	64 to 68	66	53 to 64	60	-6
MC-5I	72 to 75	74	63 to 68	66	-8
MC-6I	53 to 57	54	61 to 64	62	+8

Table 5
Comparison of Ambient Hospital and Flight Test Sound Levels
One-Minute L_{Aeq} (4 Loudest Events)

Position	Ambient Range	Ambient Average	Flight Test Range	Flight Test Average	Sound Level Change between Averages
MC-3E	62 to 63	62	81 to 86	85	+23
MC-3I	61 to 64	62	51 to 62	57	-5
MC-5I	65 to 67	66	60 to 64	63	-3
MC-6I	46 to 50	49	56 to 60	58	+9

The results and comparisons show that the impact on community sound levels varies significantly by location. Locations close to the hospital with a direct line-of-sight to the top of the existing parking garage showed the highest increases in short-term sound levels ranging from 8 to 12 dBA at positions CP-2 through CP-4 for both five-second and one-minute L_{Aeq} readings. Conversely, community locations further away and in the flight path of the Portland Jetport showed significantly higher sound levels during ambient events (jet aircraft) than hospital flight tests. Ambient events at CP-5 and CP-8 ranged from 13 to 17 dBA higher than helicopter flight tests.

6.0 FUTURE SOUND LEVELS

The maximum sound levels that will be generated during use of the proposed helipad are not expected to exceed sound levels measured during the test flights. However, the period of sound exposure associated with a medical helicopter flight is expected to be longer than the test flights, which were approximately one-minute events at the proposed helipad.

Based on testing at Eastern Maine Medical Center in Bangor, once the helicopter lands on the helipad it will operate for approximately two minutes to spool down prior to total shutdown. Helicopter sound levels decline during the spool down sequence. Depending upon how long the helicopter spends on the pad waiting for or loading a patient, it is likely that the time period from start to liftoff will approach or exceed three and a half minutes. Helicopter sound levels increase gradually from startup to liftoff. When a patient is delivered to the hospital, the amount of time on the helipad may be shorter depending upon whether the helicopter will shutdown completely or drop off the patient and depart immediately.

Future sound levels will also be affected by proposed changes to hospital and community buildings that will result from the proposed expansion. Modifications and additions, such as a new helipad and associated elevator tower, will be made to the existing parking garage to construct the helipad facility. A second parking garage will be built adjacent to the existing parking garage and the new Charles Street Building will be built northeast of the Maine Medical Center complex adjacent to Richards Tower. These site changes will act to block helicopter noise south and east of the hospital, but will also reflect a portion of helicopter noise to the north and west.

A helipad noise model of MMC was developed utilizing topographic survey data and helicopter flight testing at Eastern Maine Medical Center. Estimates from this noise model were used to compare sound levels and assist helipad siting on the existing MMC parking garage. The results of the flight test will be used to refine the computer noise model to predict future sound levels in the vicinity of the hospital under full build-out conditions of the expansion. Incorporating flight test data into the noise model will provide estimates of future sound levels for comparison to relevant local, state and federal standards.

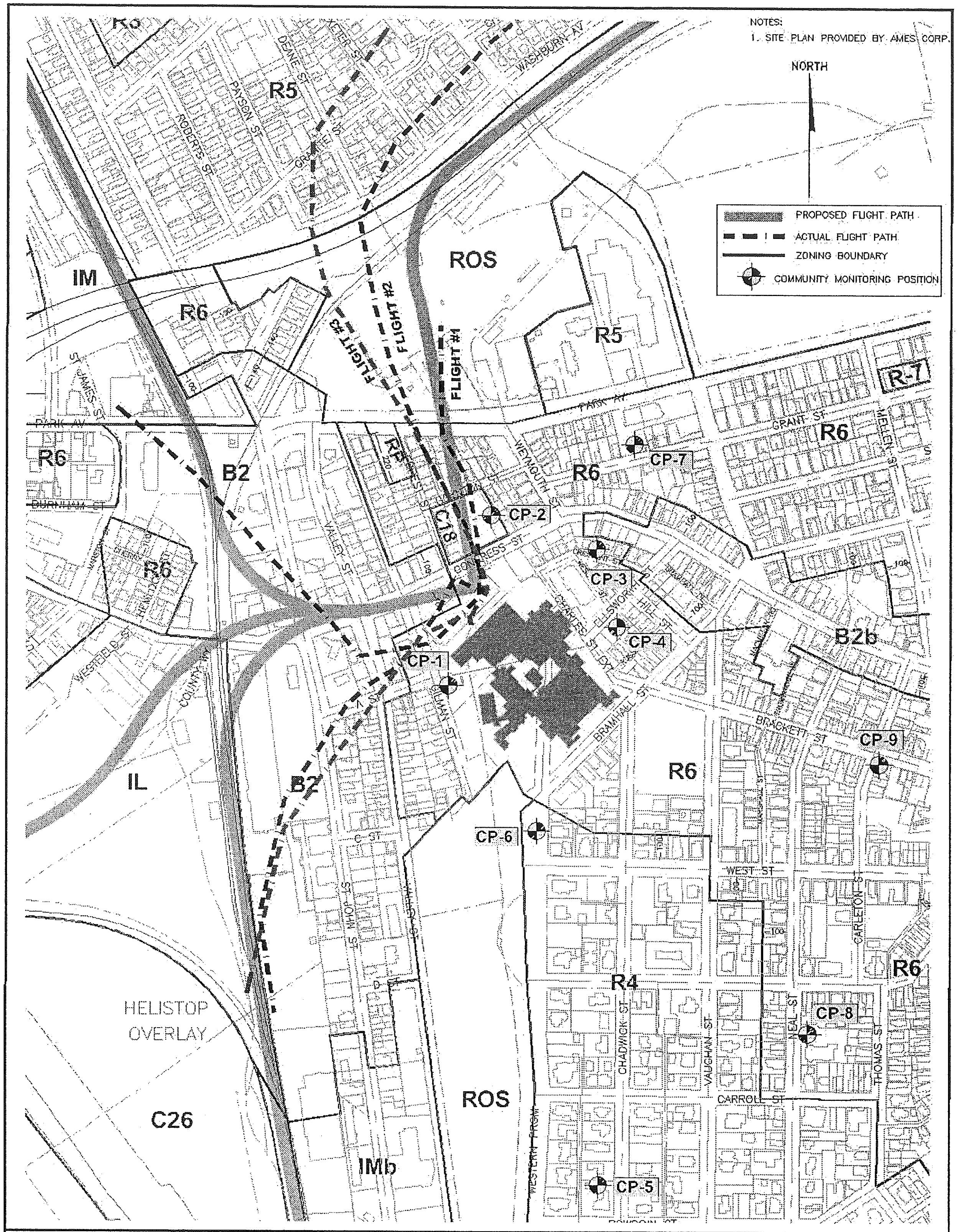
7.0 CONCLUSIONS

From monitoring results in the vicinity of Maine Medical Center, flight test sound levels can be compared directly with ambient community sound levels. Both flight test and community sound levels were measured under existing site conditions and, therefore, do not include construction of the Charles Street Building, helipad, elevator tower, and new parking garage.

The results show areas where helicopter sound levels exceeded daytime community sound levels by 8 to 12 dBA, based on five-second and one-minute L_{Aeq} readings. The results also showed areas near the hospital where helicopter sound levels were at or below existing daytime community sound levels.

The overall impact of helicopter sound levels depends on the type and number of daytime and nighttime flights that will occur and the building configuration at the time of the flights. Incorporating this information into the analysis would provide a basis for comparison to relevant local, state and federal noise standards.

FIGURE 1. VICINITY SITE PLAN AND HELICOPTER FLIGHT PATHS



NOTES:
1. SITE PLAN PROVIDED BY AMES CORP.

NORTH

▬	PROPOSED FLIGHT PATH
▬ ▬ ▬	ACTUAL FLIGHT PATH
—	ZONING BOUNDARY
⊕	COMMUNITY MONITORING POSITION

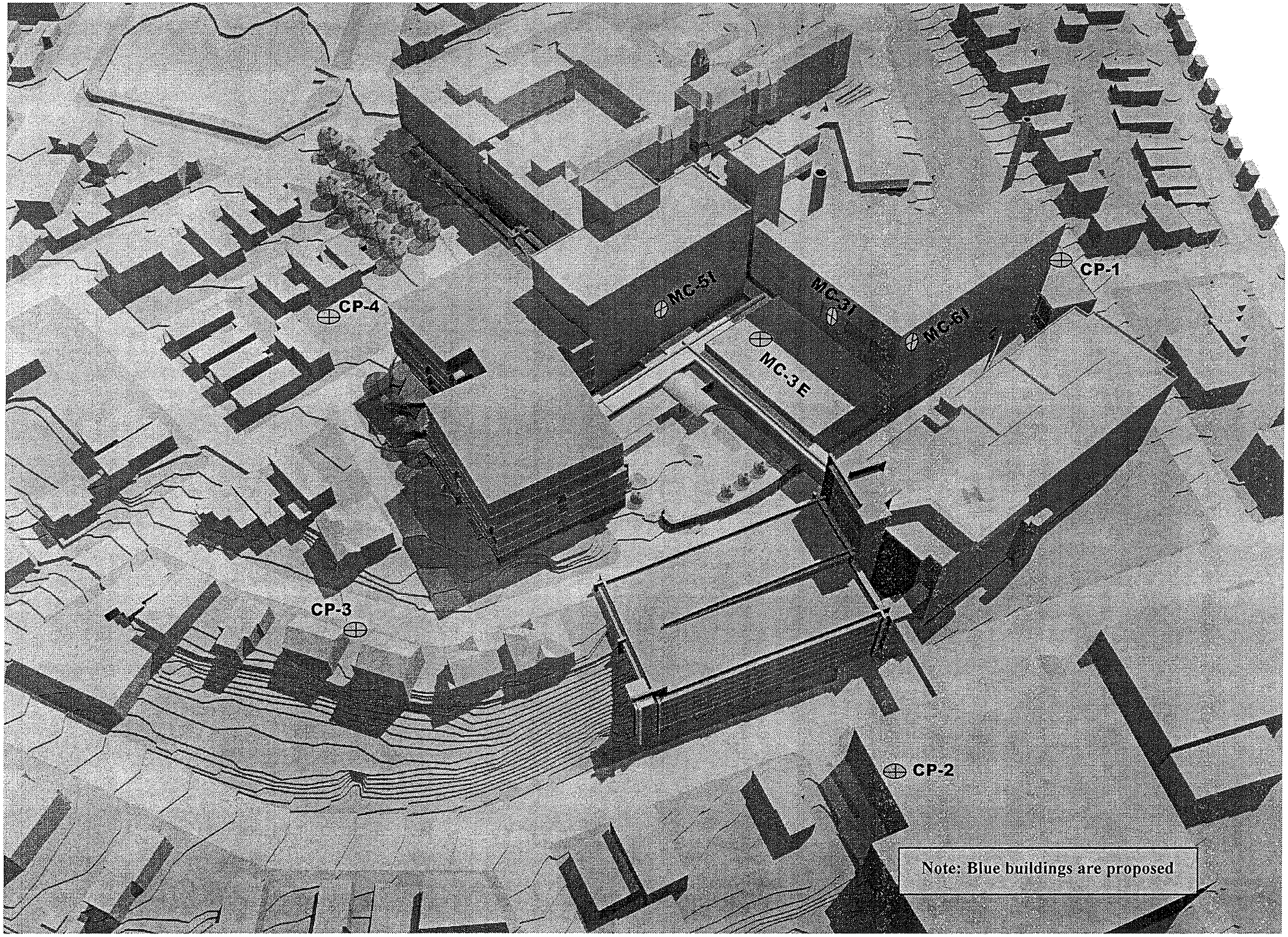
Resource
Systems
Engineering

35 Church Rd.
P. O. Box K
Brunswick, Maine
(207) 725-7896

MAINE MEDICAL CENTER
VICINITY SITE PLAN
PORTLAND, MAINE

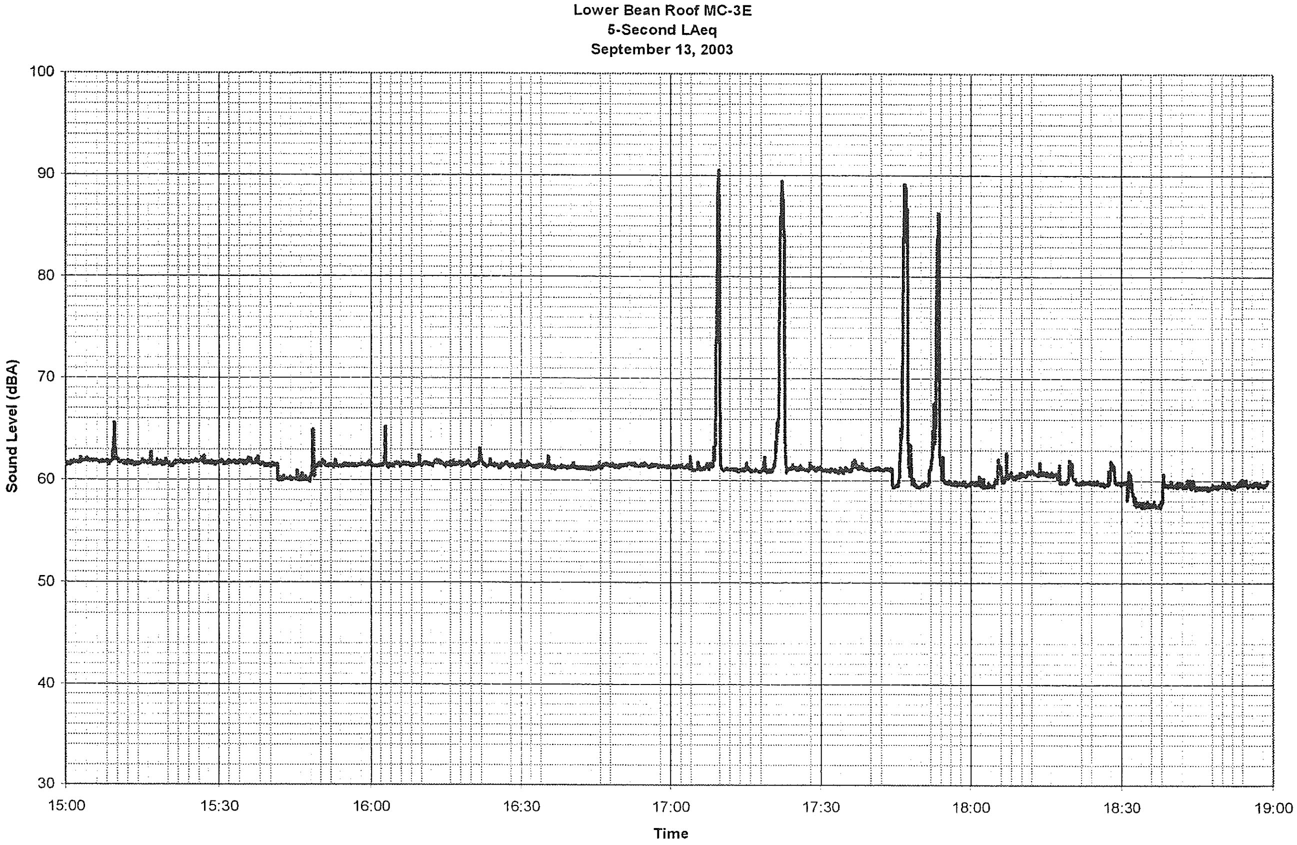
DWG NO.: VSP-01
PROJECT: 010120
DRWN: RHM
CHECK: RSB
SHEET: 1 OF 1
REV: 1
DATE: 4-14-04
APP'D:

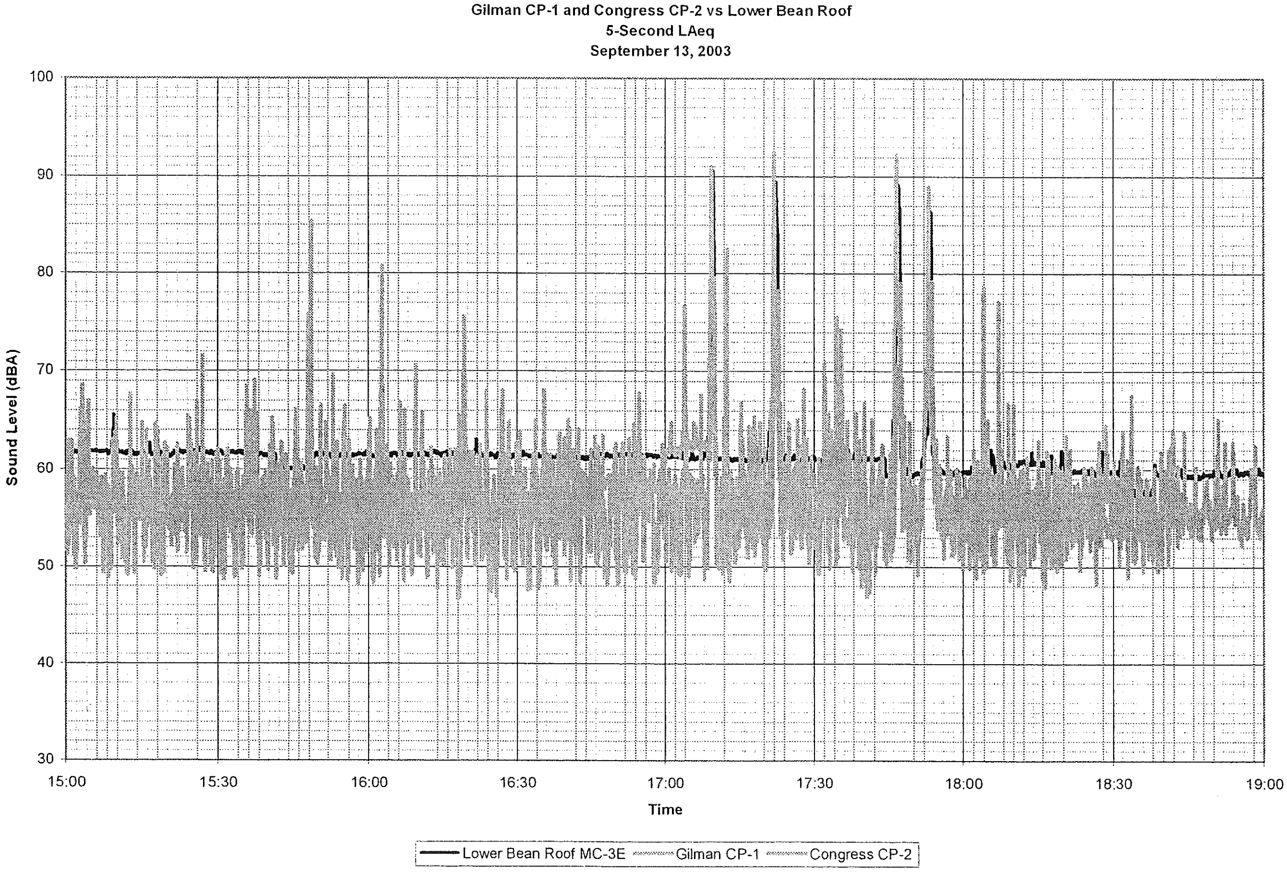
FIGURE 2. MAINE MEDICAL CENTER SOUND MONITORING POSITIONS AND HELIPAD LOCATION



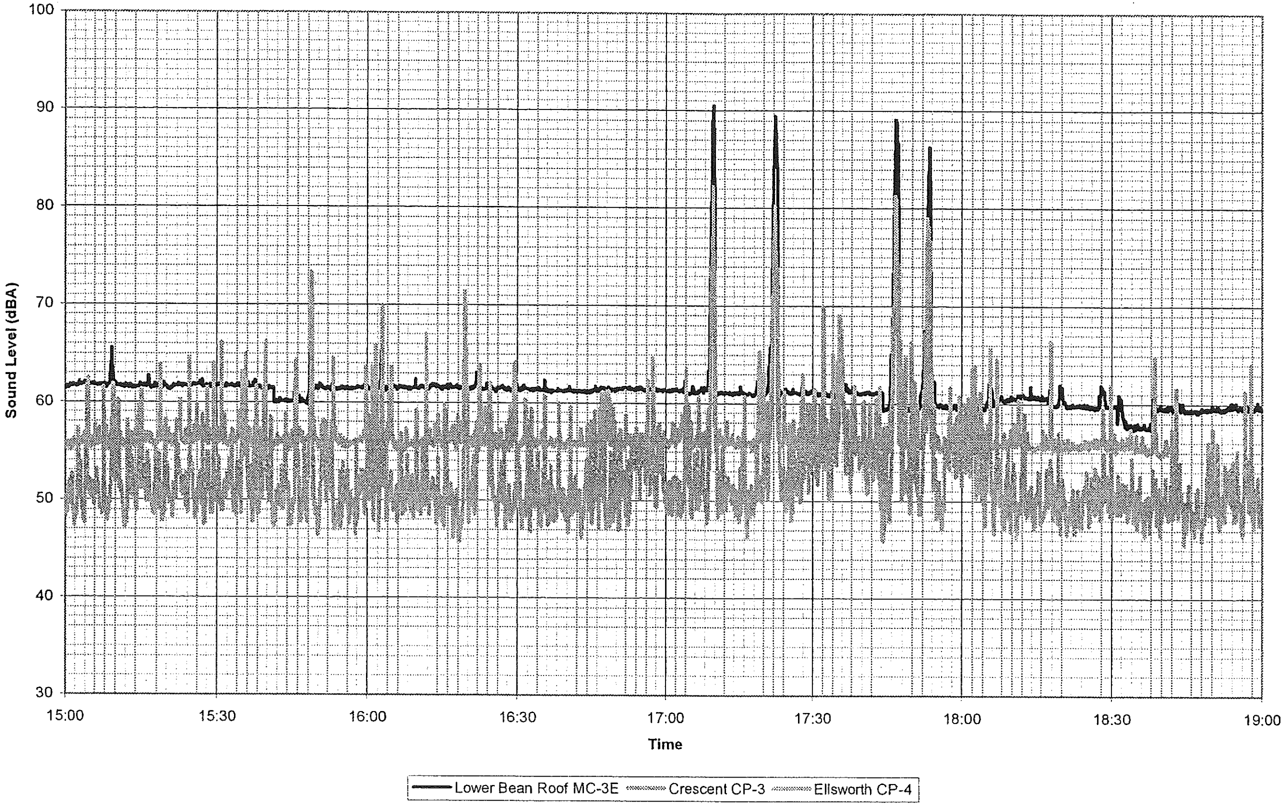
Note: Blue buildings are proposed

FIGURE SET 1. COMMUNITY MONITORING POSITIONS AND MMC ROOFTOP POINT 5-SECOND RESULTS

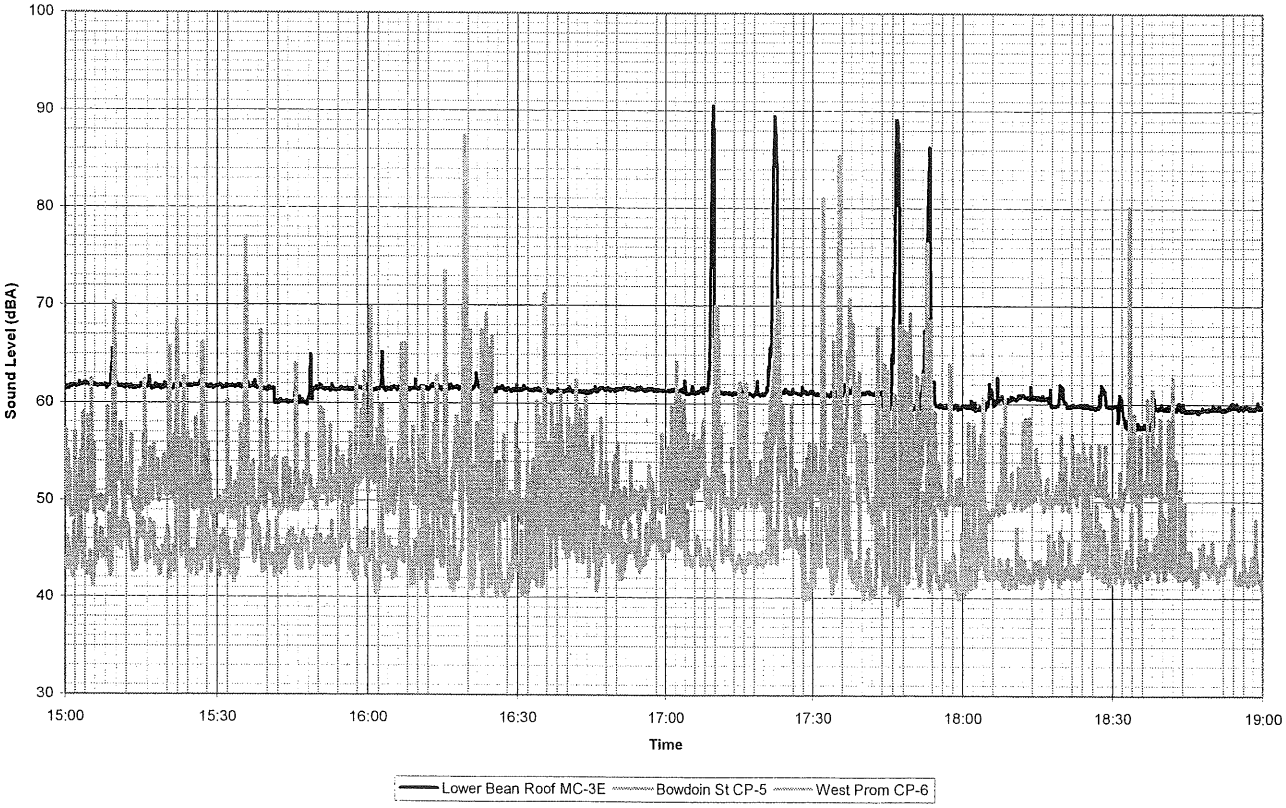




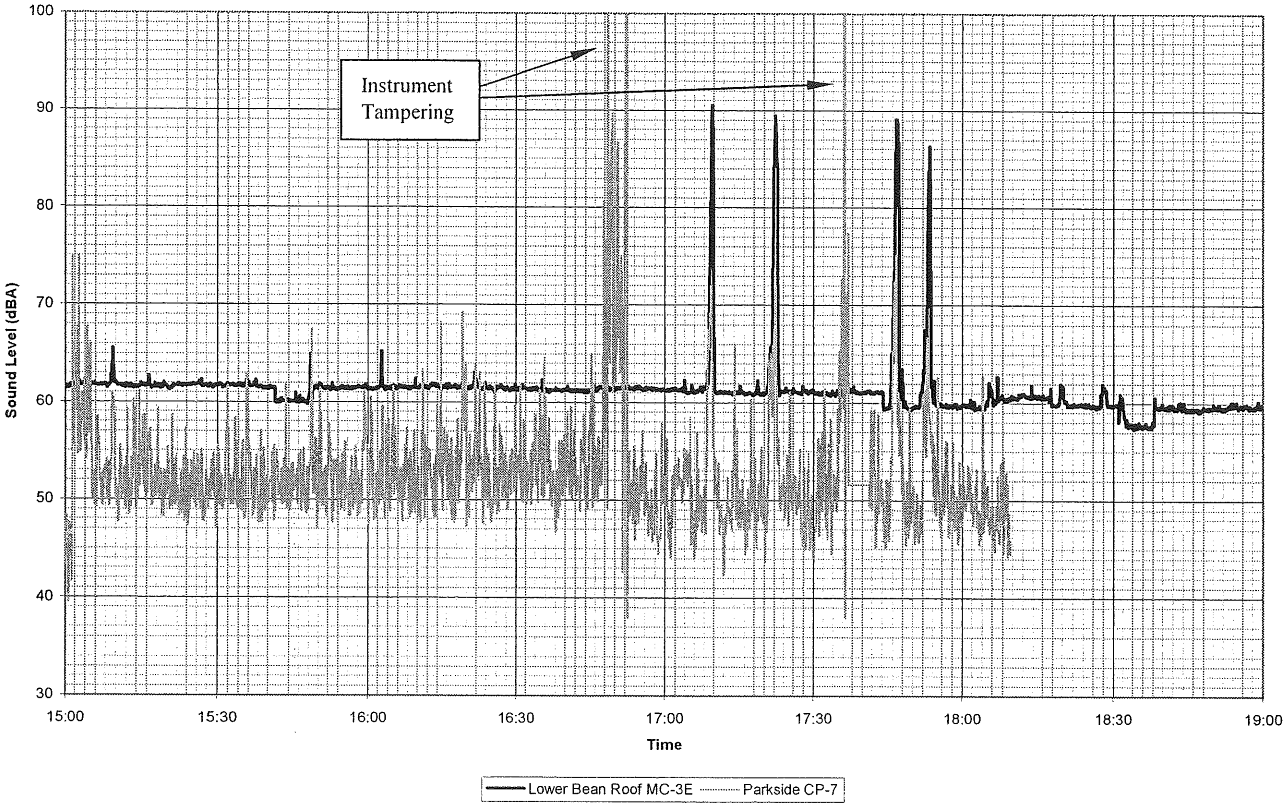
Crescent CP-3 and Ellsworth CP-4 vs Lower Bean Roof
5-Second LAeq
September 13, 2003



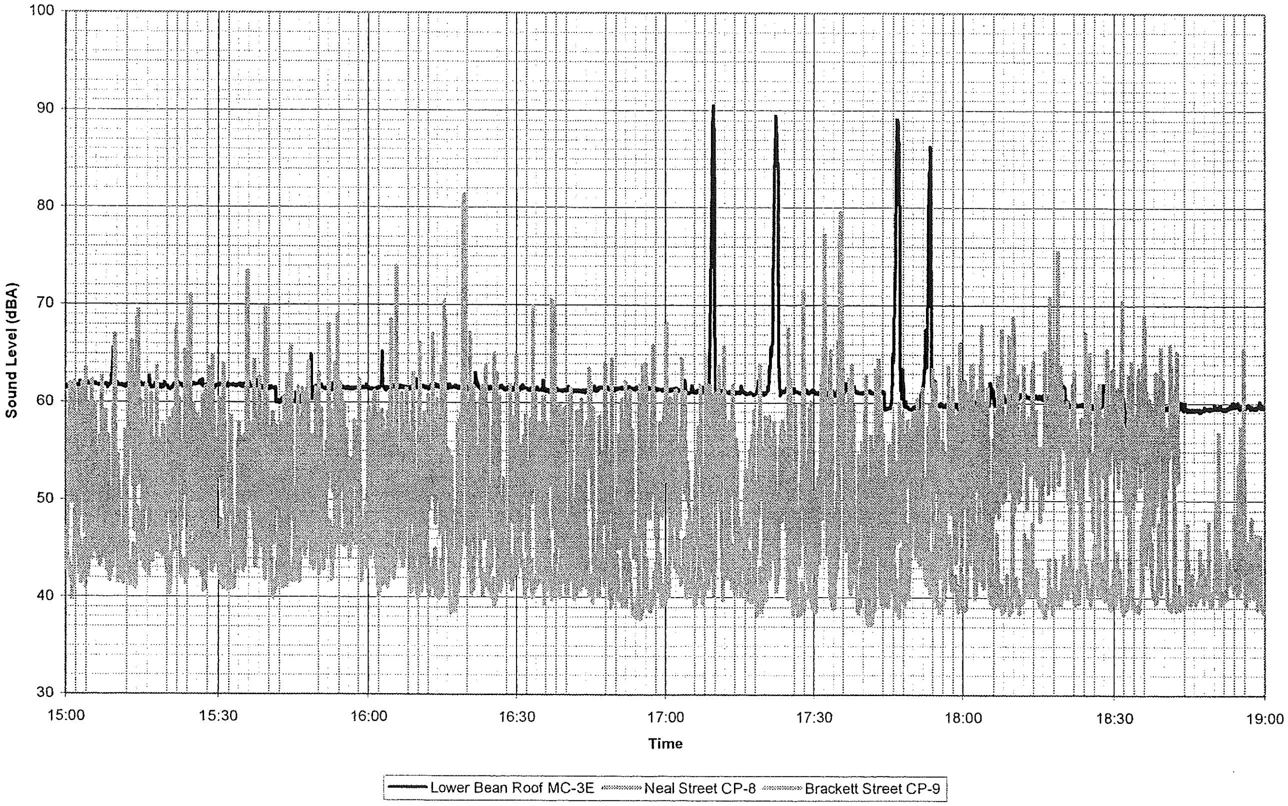
Bowdoin St CP-5 and West Prom CP-6 vs Lower Bean Roof
5-Second LAeq
September 13, 2003



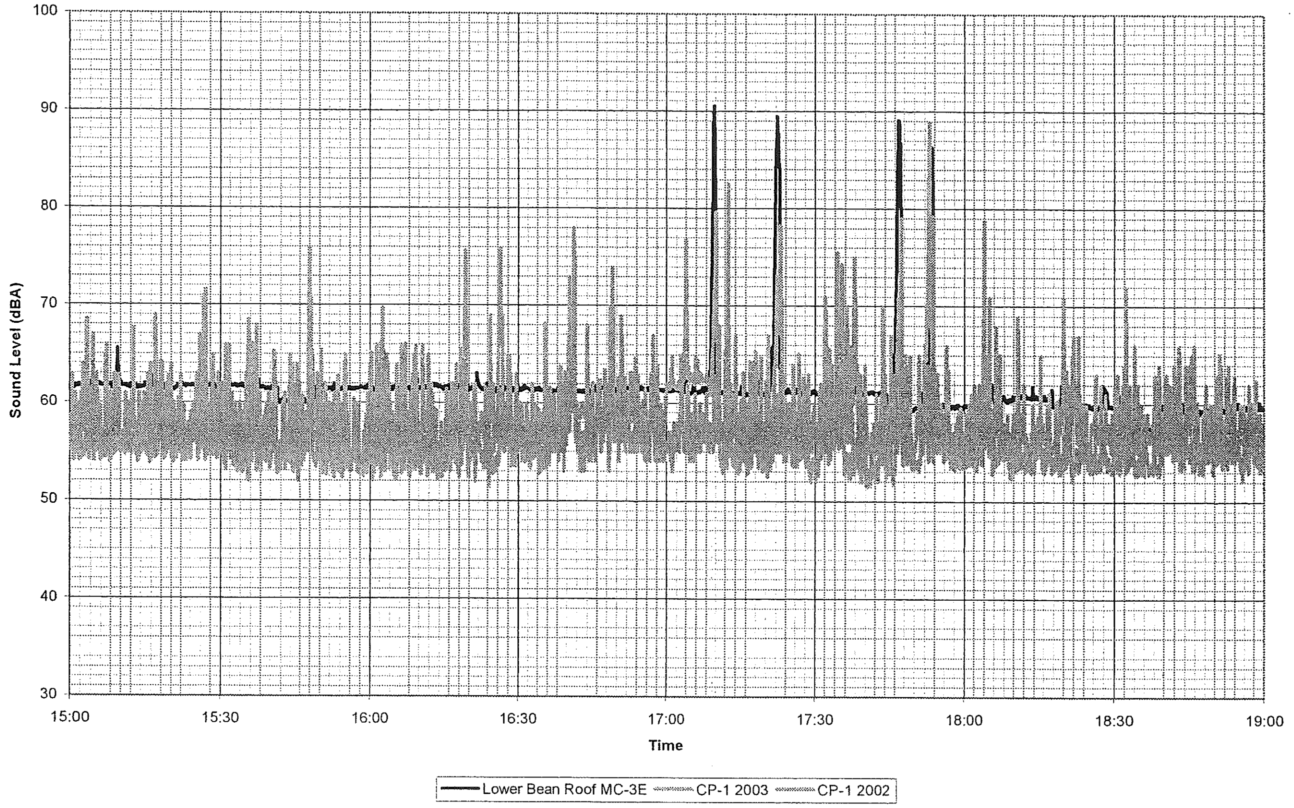
Parkside CP-7 vs Lower Bean Roof
5-Second LAeq
September 13, 2003



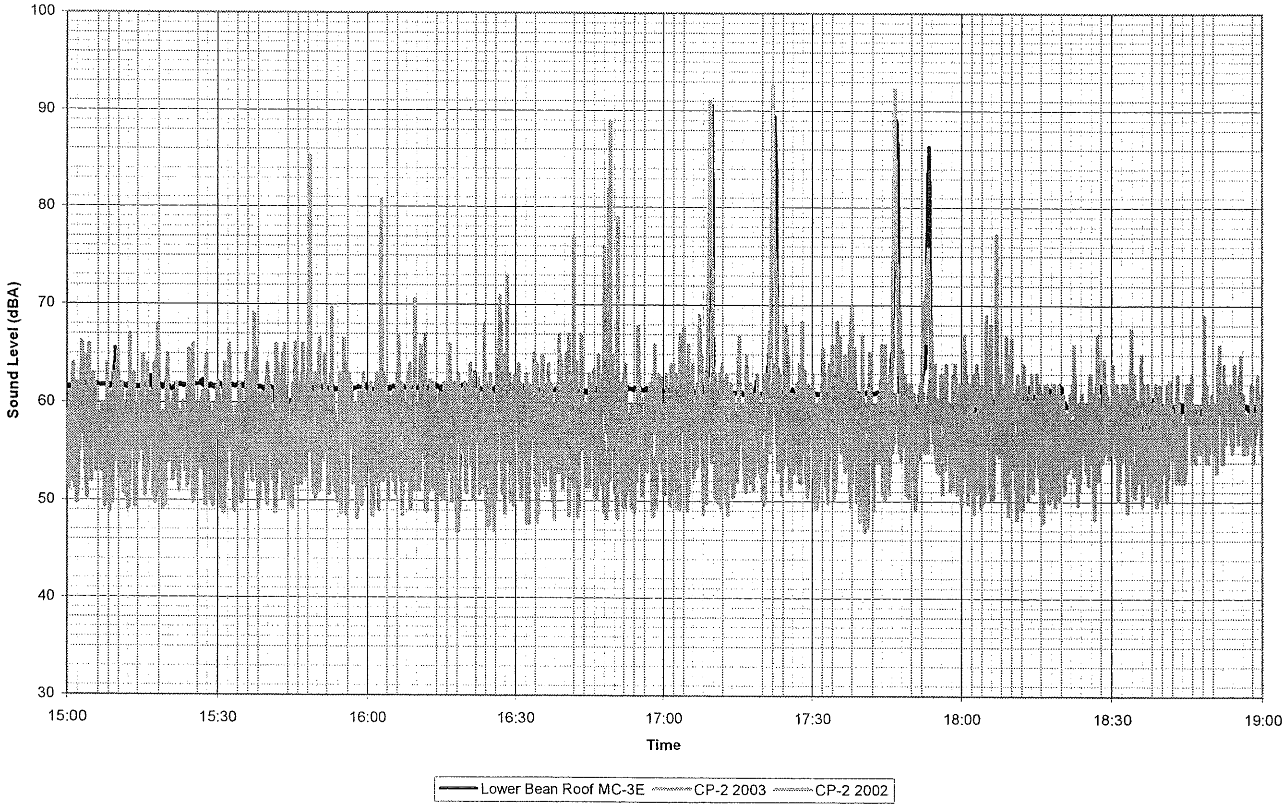
Neal St CP-8 and Bracket St CP-9 vs Lower Bean Roof
5-Second LAeq
September 13, 2003

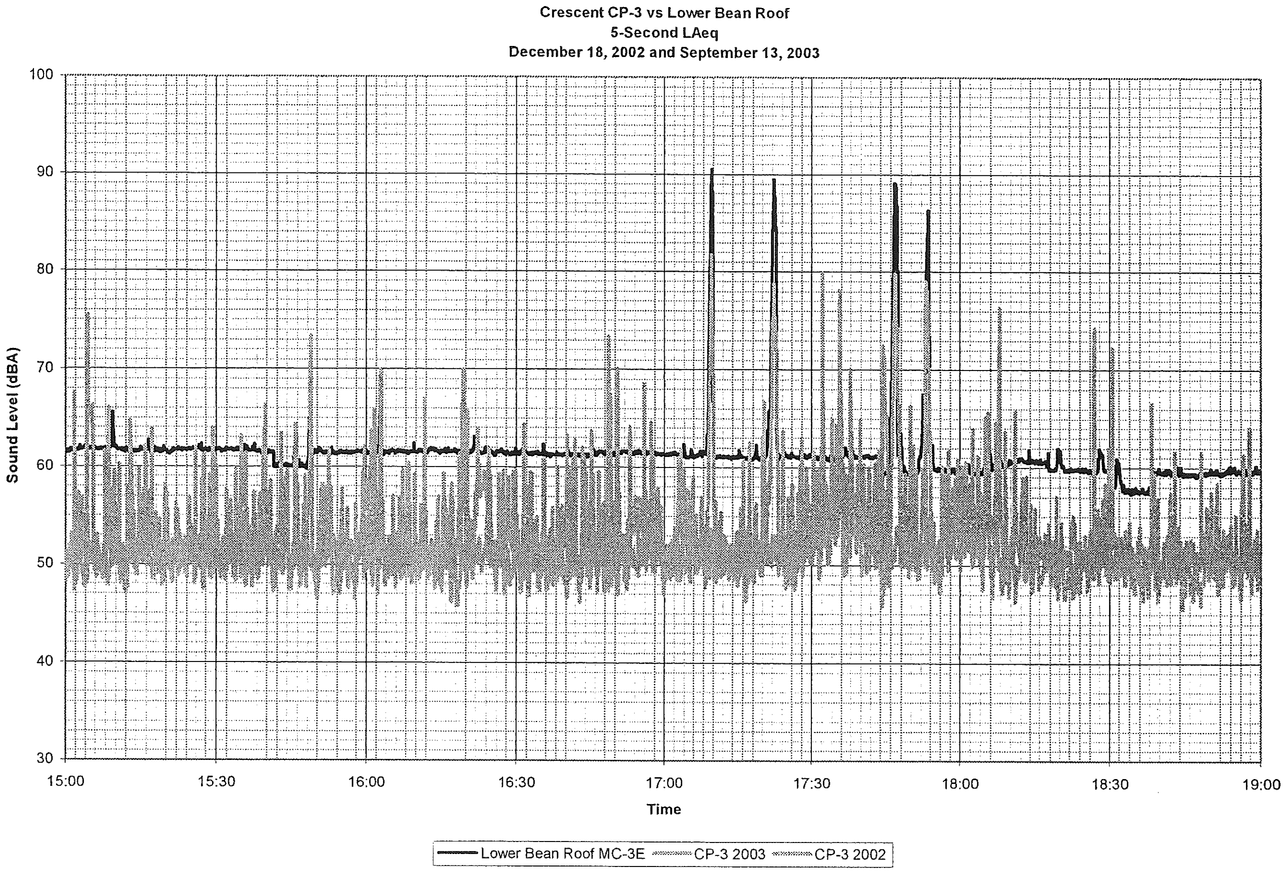


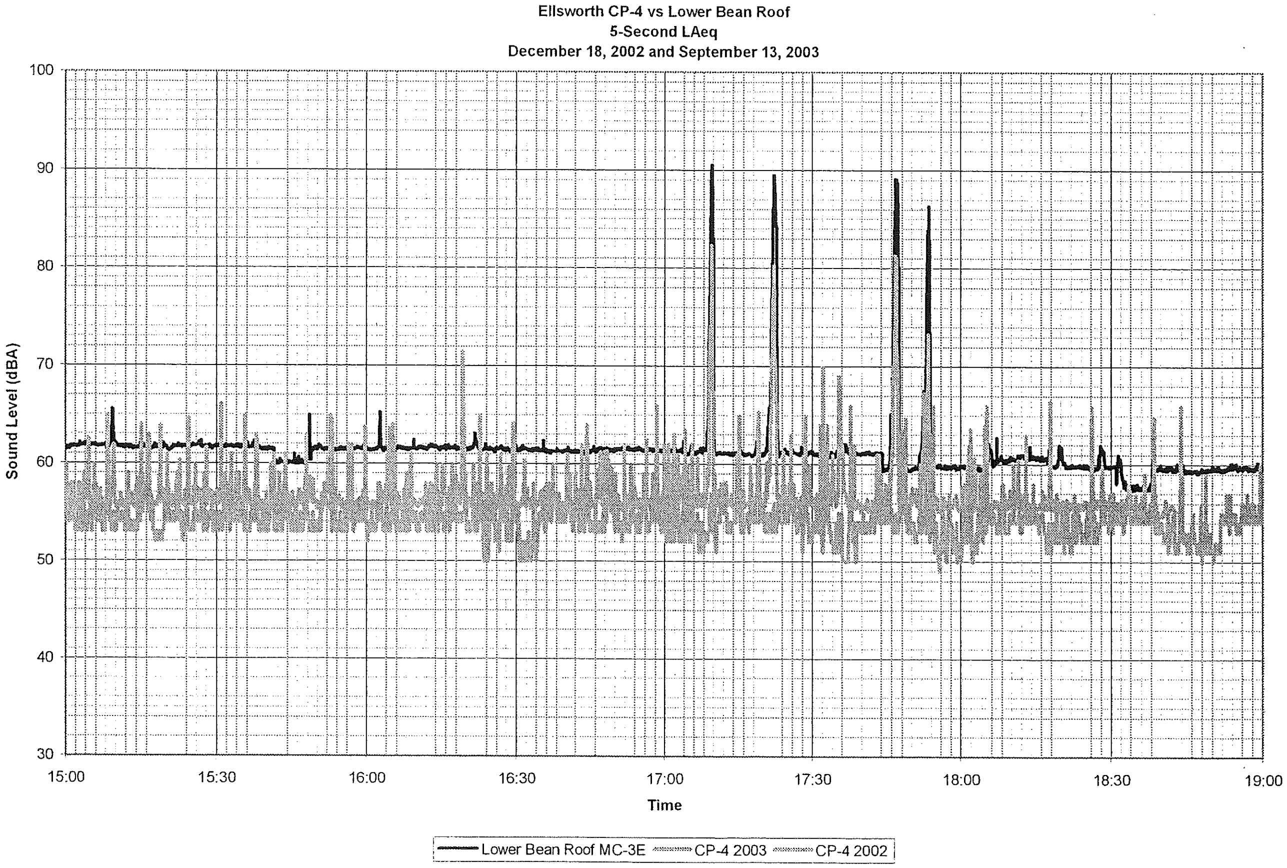
Gilman CP-1 vs Lower Bean Roof
5-Second LAeq
December 18, 2002 and September 13, 2003



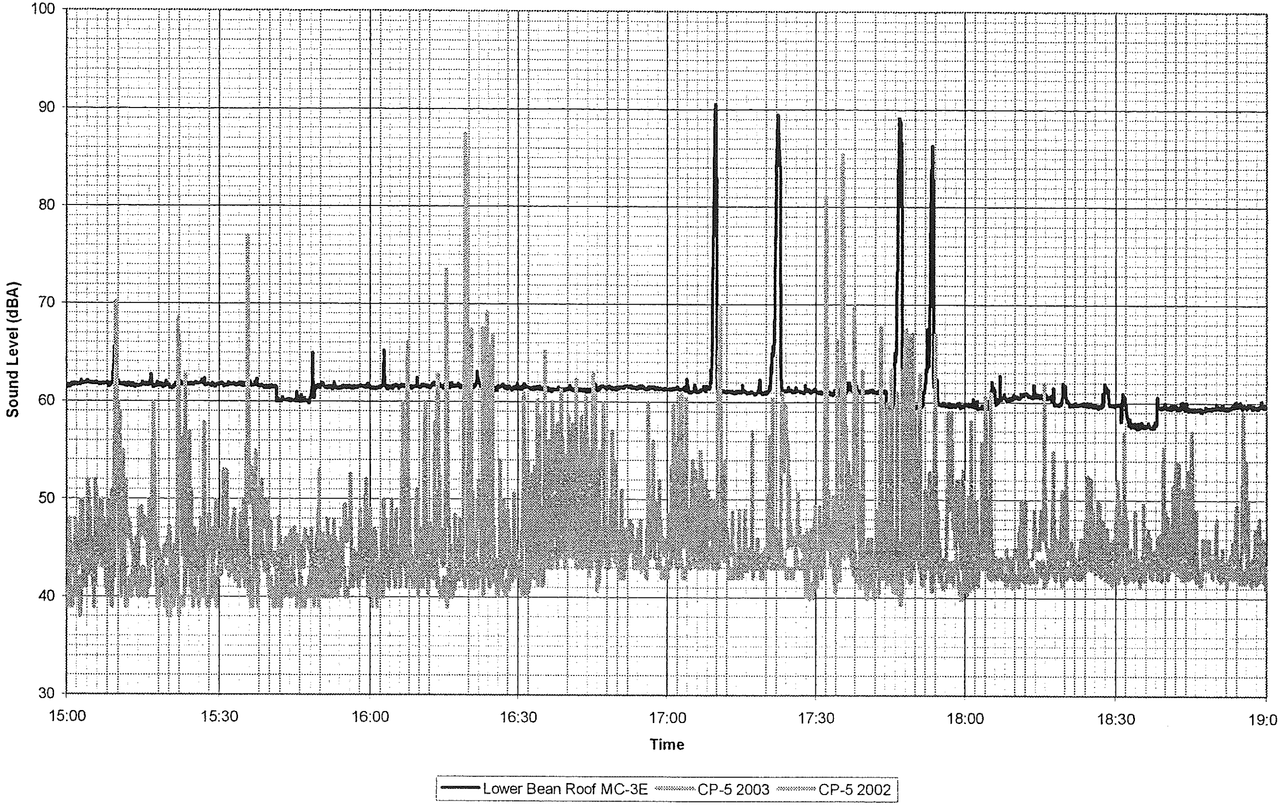
Congress CP-2 vs Lower Bean Roof
5-Second LAeq
December 18, 2002 and September 13, 2003




Crescent CP-3 vs Lower Bean Roof
5-Second LAeq
December 18, 2002 and September 13, 2003


Ellsworth CP-4 vs Lower Bean Roof
5-Second LAeq
December 18, 2002 and September 13, 2003

Bowdoin St CP-5 vs Lower Bean Roof
5-Second LAeq
December 18, 2002 and September 13, 2003



West Prom CP-6 vs Lower Bean Roof
5-Second LAeq
December 18, 2002 and September 13, 2003

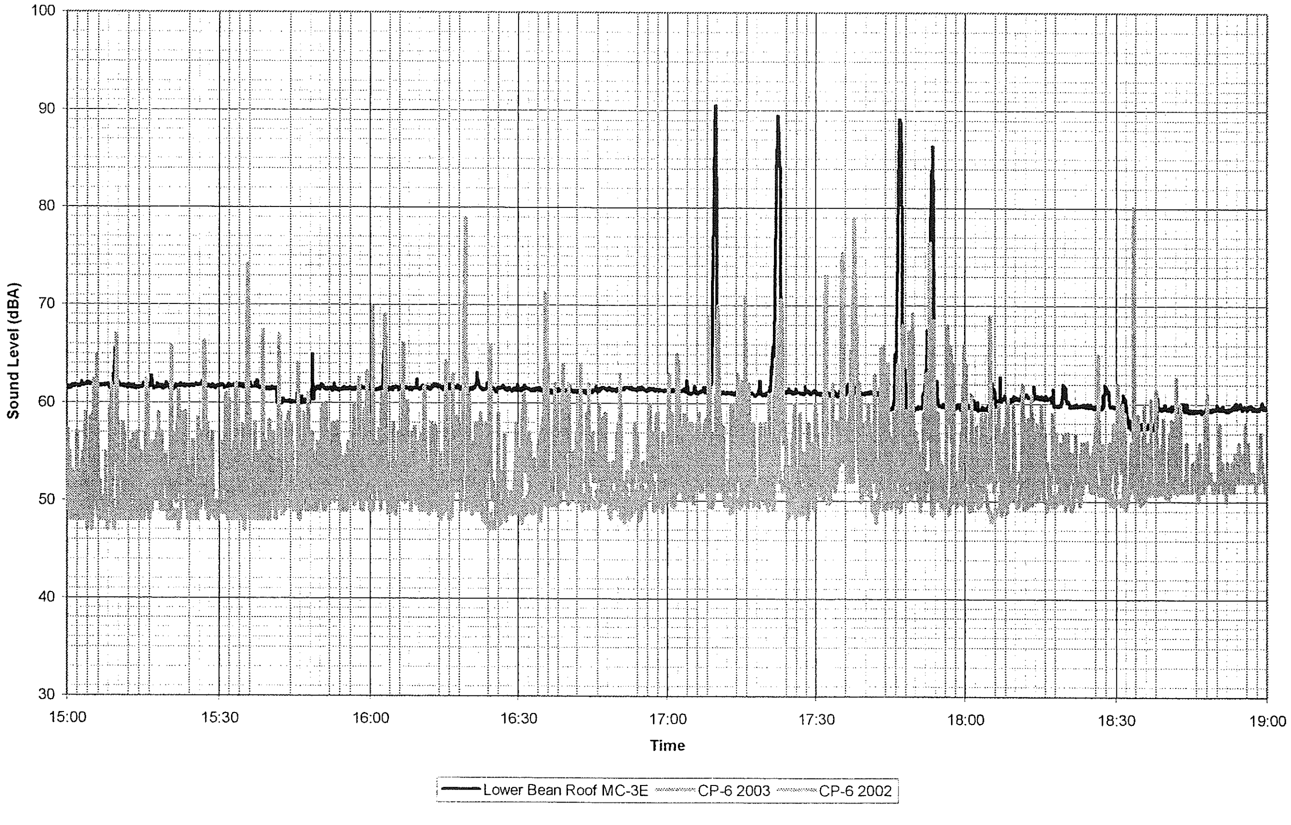
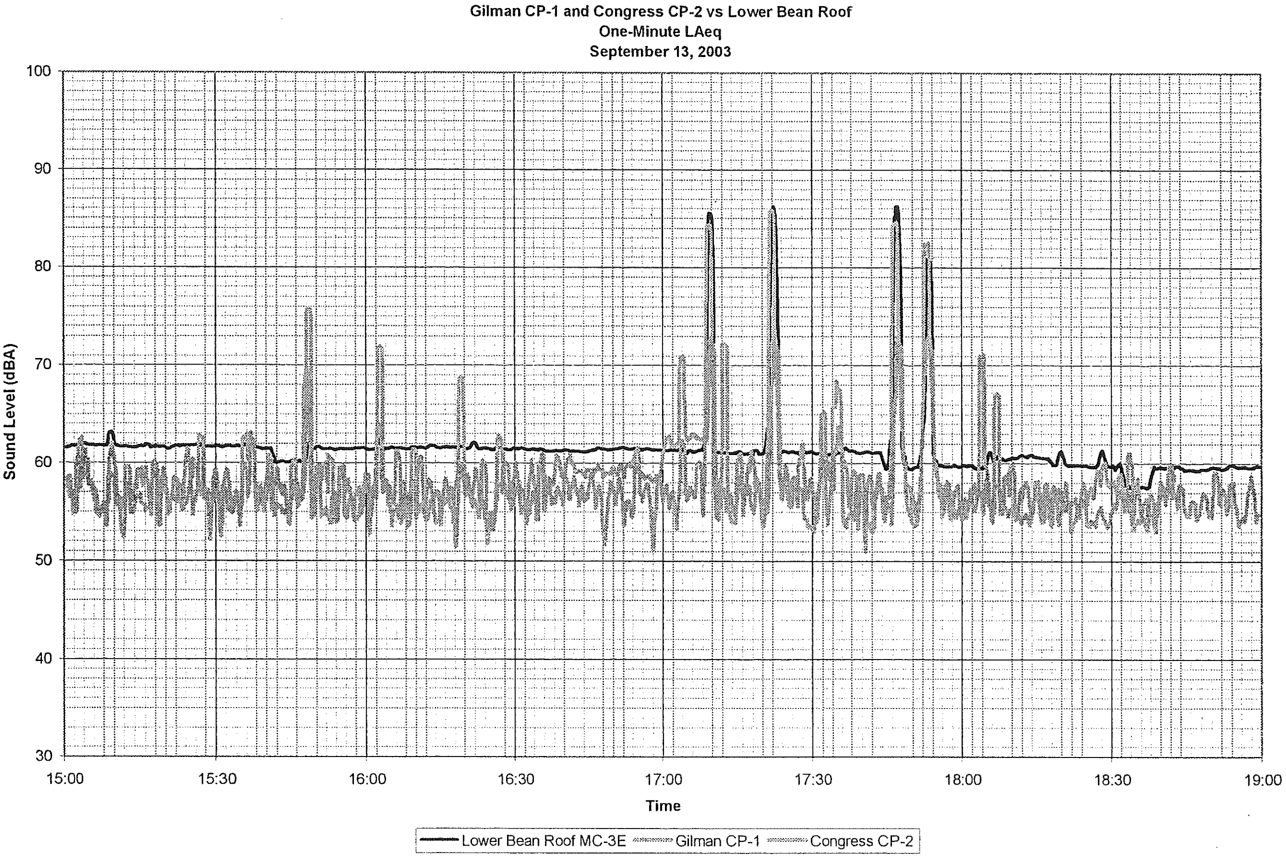
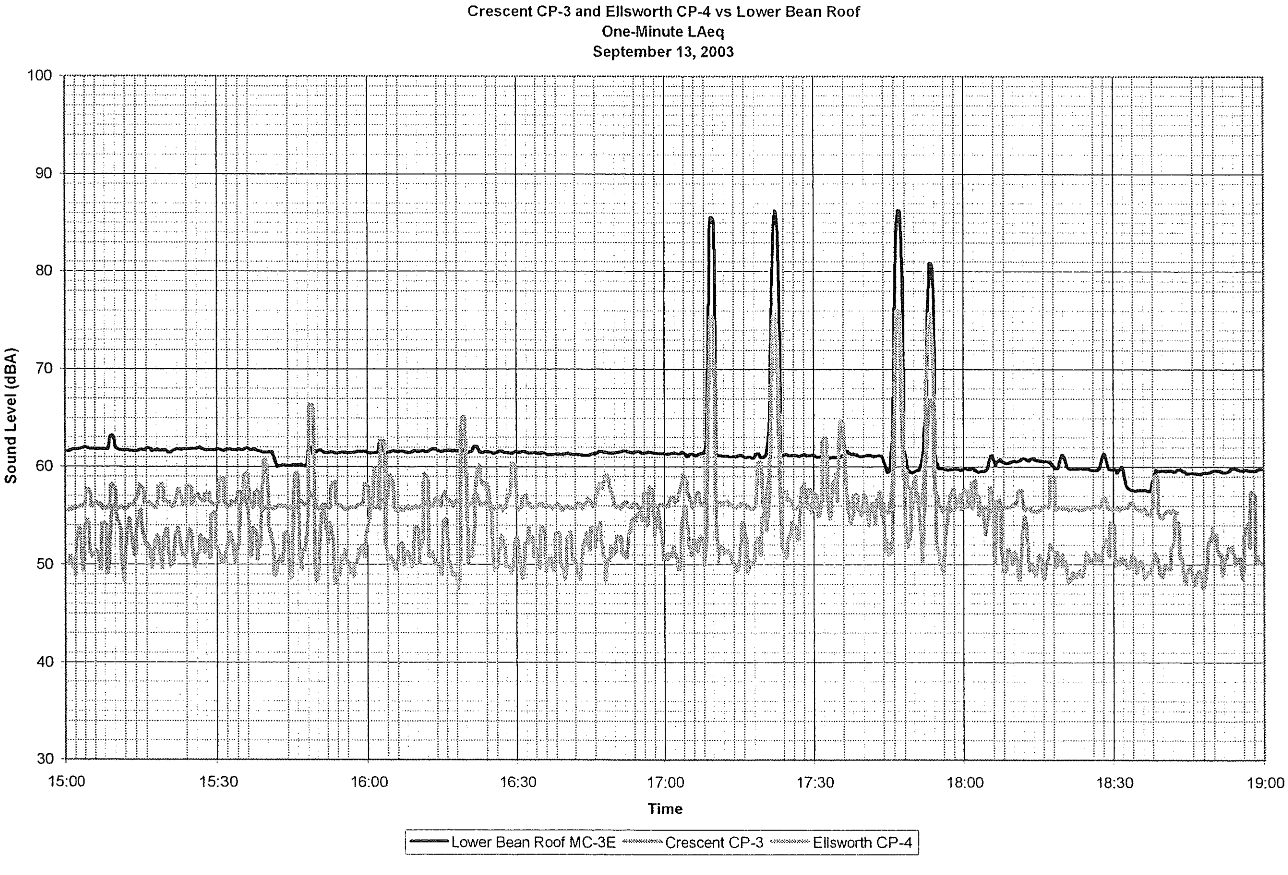
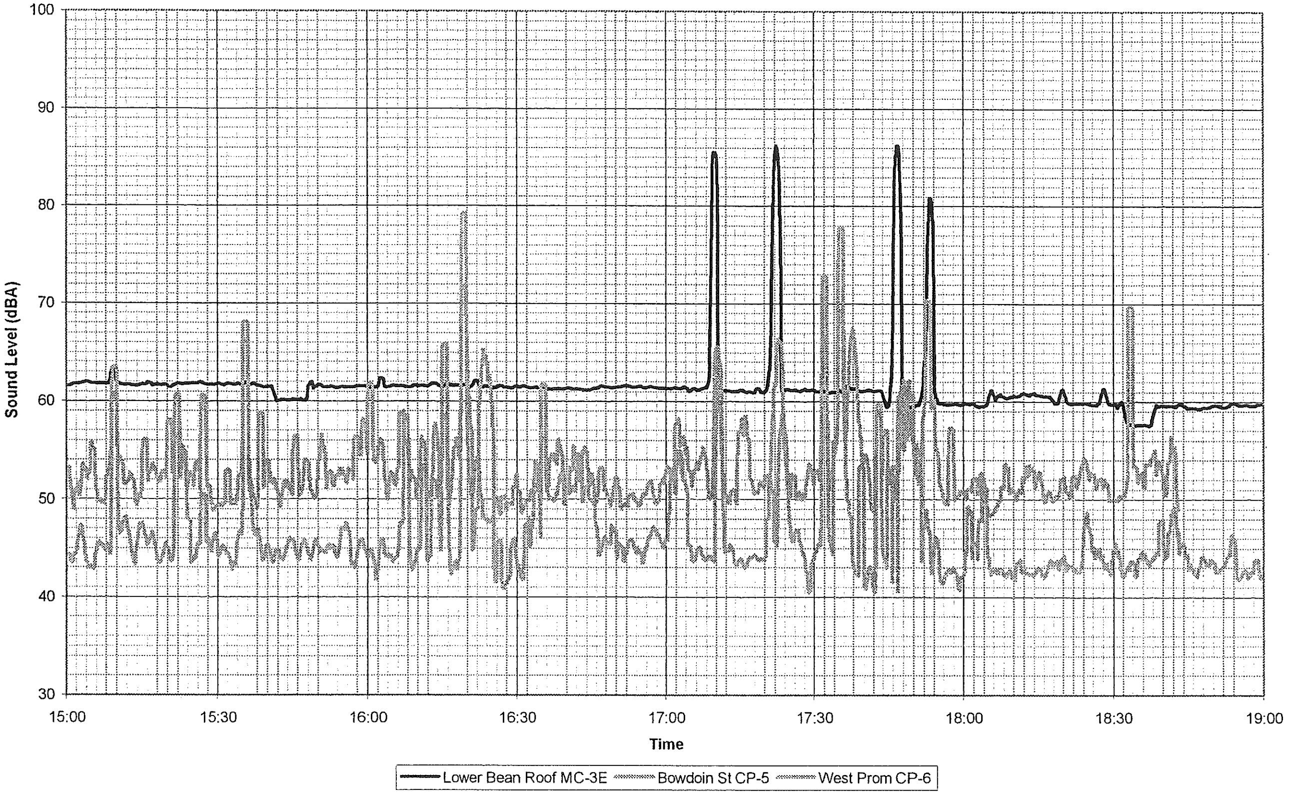


FIGURE SET 2. COMMUNITY MONITORING POSITIONS AND MMC ROOFTOP POINT ONE-MINUTE RESULTS

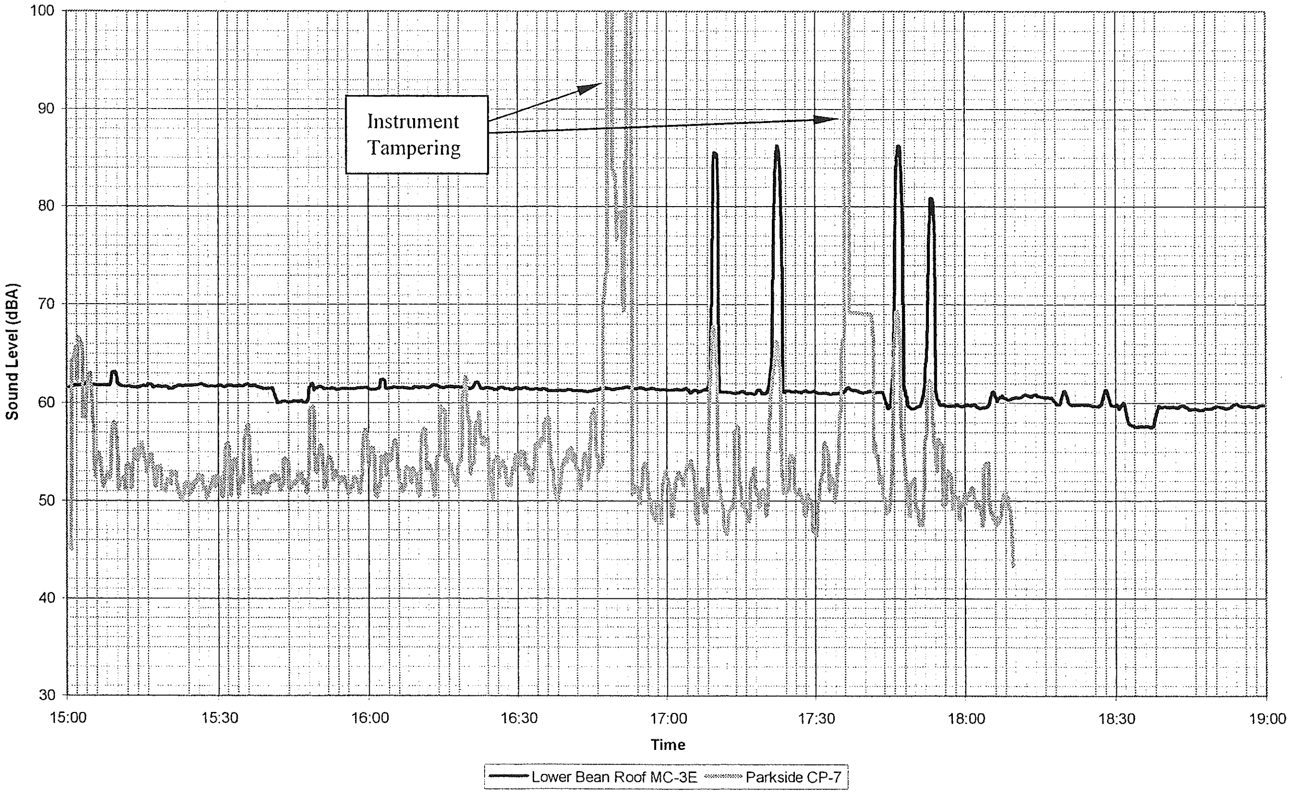


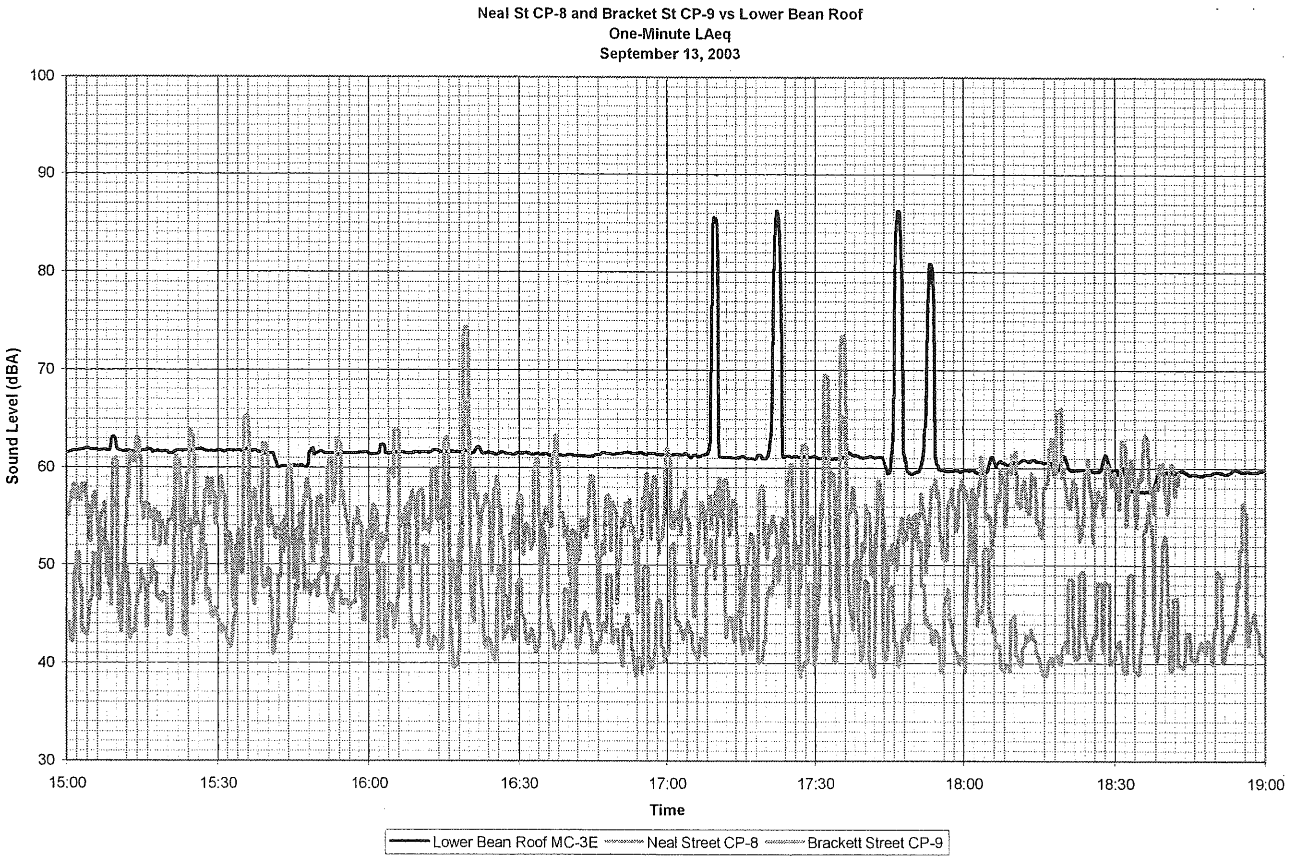


Bowdoin St CP-5 and West Prom CP-6 vs Lower Bean Roof
One-Minute LAeq
September 13, 2003



Parkside CP-7 vs Lower Bean Roof
One-Minute LAeq
September 13, 2003




Neal St CP-8 and Bracket St CP-9 vs Lower Bean Roof
One-Minute LAeq
September 13, 2003
Sound Level (dBA)
100
90
80
70
60
50
40
30
15:00
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
Time
Lower Bean Roof MC-3E
Neal Street CP-8
Brackett Street CP-9

HARRIS MILLER MILLER & HANSON INC.
15 New England Executive Park
Burlington, MA 01803
Tel. (781) 229-0707
Fax (781) 229-7939

Tab 8

MEMORANDUM

To: Alex Jaegerman, Sarah Hopkins
Department of Planning and Development
City of Portland, Maine

From: Robert L. Miller

Subject: Review of Mitigation Measures Discussed with MMC on 19 October 2004

Date: 6 January 2005

At a meeting held at the City of Portland's Department of Planning and Development on 19 October 2004, City, Greater Portland Council of Governments, MMC, LifeFlight of Maine, RSE, and HMMH representatives discussed progress made in evaluating various noise mitigation measures applicable to the proposed helipad. The two primary topics were the design of the helipad itself to serve as a noise barrier for nearby residents, and results of the flight tests conducted on 23 September for the purpose of identifying appropriate flight patterns to and from the proposed facility.

Helipad Design

Regarding the helipad design, MMC presented new information on the size, shape, noise reduction potential, and cost of the pad, reconfigured to comply with FAA safety criteria. Major design changes included elimination of sloped edges to serve as a noise barrier requiring, instead, expansion of the helipad dimensions to 70 by 110 feet with a 10-foot extension over the edge of the parking garage towards Congress Street in order to emulate previously identified noise-reduction benefits. In addition, MMC identified an FAA requirement for an additional 5 feet of safety netting surrounding the entire pad. The incremental cost of the expanded pad was estimated to be on the order of $750,000 with noise-reduction benefits of only 2 to 4 decibels at nearby residences. HMMH concurs that this is an extraordinarily high cost for the limited improvement that it would provide.

Sound Insulation Alternative

As an alternative to the larger pad, HMMH suggested that MMC retain the original surface area of the pad and investigate the possibility of providing sound insulation to the closest residences. FAA provides 80- to 90-percent funding assistance for such mitigation in airport environs where noise exposure levels are sufficiently high, and although no funding assistance would be expected in this instance, indoor noise levels could be reduced well below the 2- to 4-dB reductions of the noise barrier at significantly less cost if implemented at a limited number of buildings. Also, the visual impact of the helipad would be significantly reduced commensurate with its smaller size.

Following the October meeting, HMMH estimated that Sound Exposure Levels (SELs) from Agusta 109 operations could be on the order of 90 to 95 dBA or more outdoors at nearby homes whenever the helicopter is in transition landing or taking off from the pad. Sound insulation treatments to reduce these levels to acceptable indoor levels would have to include installation of new acoustically-designed windows having a Sound Transmission Class (STC) of 35 or greater, plus installation of central air conditioning. A central air or other central ventilation system is considered a necessary element of an effective sound insulation program because it provides an alternate source of fresh air so that, at the discretion of the resident, windows and doors may be left closed during warm weather to take full advantage of the noise reduction benefits of the new window installations.

Central air conditioning, as opposed to through-the-window or through-the-wall air conditioners, is considered necessary to avoid compromising the noise reduction benefits of the windows when closed. No other treatments are considered necessary to reduce levels below those desired for minimal sleep disruption. Treatments are normally implemented on a voluntary basis; no homeowner would be required to accept the modifications if he or she did not want them.

Assuming that noise abatement flight tracks are followed essentially as outlined below, residences potentially eligible for sound insulation treatment would include those along Congress Street from the building directly opposite the new parking garage (designated receiver location RH-3 in MMC's report of 10/11/04) west to Valley Street. Other than RH-3, the residential units in that area appear to be mostly multi-family row houses over first-floor commercial space.

Noise Abatement Flight Paths

Results of the September flight tests, while informative and well received by interested observers, did not produce quantifiable data to help determine optimum flight corridors for noise abatement. Though some observers reported certain of the tests to be quieter than others, the observers' conclusions were largely influenced by their own particular location relative to the flight paths flown, and not all locations around the proposed helipad site were represented equally. As a result, attendees at the October meeting concurred that the noise abatement flight paths recommended by HMMH based on least population overflown should be incorporated into the Conditional Zone Agreement and that monitoring and review of the recommended corridors should be conducted on a quarterly basis as presently defined in paragraph 6(b) of the draft Agreement dated 6 July 2004. It is suggested that the figure attached to this memorandum, which illustrates the desired corridors, be included as Exhibit B of the Agreement as referenced on page 7 of the draft. It is also recommended that wording in the Agreement be added or modified to reflect HMMH's related suggestions identified in italics in our 22 July memorandum and reproduced below with minor edits:

- *Noise abatement corridors to and from the northeast, northwest, and west as shown in Exhibit B are recommended for use whenever patient condition and weather permit. Under non-emergency conditions, the preferred route for helicopters approaching or leaving the helipad is to enter or exit the area from or to the west, crossing the shoreline of the Fore River just east of the Interstate 295 bridge.*

- *Pilots should maintain as high an altitude as possible on approach, descending at 12 to 15 degrees when making their final approach to the pad. Ideally, pilots should maintain level flight at or above 1,000 feet MSL except when climbing or descending to the helipad within approximately one mile from the MMC.*

- *Patient condition and weather permitting, a pilot will maneuver his/her helicopter so that is oriented on the pad on a heading of approximately 360 degrees whenever possible.*

Other

Paragraphs 6(c) and 6(d) of the July 6th draft Agreement are also appropriate controls for operation of the helipad and should be retained in the final Agreement