# Safety on the WPI Campus

## An Information System for Buildings' Fire-Safety Equipment

An Interdisciplinary Qualifying Project
Submitted to the faculty of
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# 1 Abstract

This project developed an information system to manage fire-safety equipment data on the WPI campus. The system aided in modernizing the record-keeping process at Plant Services, by providing the capability to track safety equipment.

A database was created for Fire-Safety equipment located in five buildings. CAD drawings were updated and safety equipment was indicated by symbols on a campus map. The database and CAD drawings were linked by Graphical Information System software. The protection coverage was calculated, and the fire-code compliance was evaluated.

# 2 Executive Summary

Building fire-safety is a critical issue on every college campus. At WPI, several IQP projects have addressed improving campus safety. This IQP project was undertaken to contribute to modernizing and improving campus building safety record-keeping. By updating CAD architectural floor plan drawings, creating an electronic equipment database, and building a computer system with GIS software to work with the spatial information, this project has provided Plant Services at WPI the capabilities to analyze and track building safety code compliance while offering streamlining to its safety equipment maintenance process.

The computer analysis of the data collected for this project evaluates the quantity and placement of fire-safety equipment within five WPI campus buildings. Calculations indicate the actual protection coverage that each safety device can be expected to provide, and allows for the evaluation of safety code compliance for each of the five campus buildings sampled.

From this project work, several improvements have been made available to the Plant Services safety record-keeping process. CAD drawings of five campus building floor plans have been standardized and updated, enabling contractors to see equipment identification and location indicated by icons that cross-reference their other records. Equipment records for campus building safety have been organized into an electronic database to ease the maintenance and compliance inspections for the five buildings. Finally, for the five buildings sampled, building safety code compliance coverage can be calculated on demand, for each type of building fire-safety equipment presently installed.

# 3 Introduction

Fire safety has always been an important issue in the public-eye. In recent memory, local fire accidents have further enhanced public awareness of fire-safety issues, particularly regarding the potential dangers of unsafe publicly occupied buildings.

About five years ago here in Worcester, a devastating warehouse fire claimed the lives of six firemen, showing that fires not only effect the building occupants, but also the fire-fighters, the families of the victims involved, and the community at large.

Last year, a tragic fire in a Rhode Island night-club called "The Station" resulted in the loss of 100 lives. This incident served as a reminder to the public of the dangers of an uncontrolled fire in an unsafe building. In hindsight of this tragedy, numerous building hazards have been identified, each of which pointed to a rise in the number of fatalities and loss of property: locked fire-exits, available fire-exits that were unused because they were not adequately labeled or visibly illuminated, building modifications involving the use of highly-combustible building materials, a possible capacity in excess of the maximum certified occupancy, improper building use, and lack of required permits. (The source of ignition was found to be sparks emanating from a pyrotechnic display).

In the wake of disastrous fires, the attitudes of the general public tend to shift toward raising the importance of fire-safety and fire-emergency preparedness. When the public demands that safety measures be increased, the elected local, state, and federal governments respond by passing new laws and ordinances to enact standards that help to require a minimum level of safety measures for public buildings. As a result of such new legislation, building fire codes and fire code inspection policies are revised for fire-safety and building-safety with the aim to avoid similar tragic accidents in the future.

The public should be made aware of potentially dangerous situations arising when older buildings are opened for public use. The risk in such cases is that individuals using a public building may presume the building to be fire-safe, without actually knowing its degree of compliance with current fire-safety codes.

Safety experts who study fire accidents know that not all fires can be prevented; however, they also know that their safety efforts will continue to reduce the risk of buildings being unsafe, which will result in better protected lives and property. It is reasonable to conclude that in order to manage the risk of fire accidents, we must improve our overall fire-safety and fire-emergency awareness and preparedness.

Recent measures taken to improve building fire-safety are designed primarily to aid building occupants to respond to an emergency situation. The fire-safety equipment installed in publicly used buildings serves to minimize the likelihood of occupant injuries and to reduce the potential loss of life and property. Numerous safety studies and statistics show that these fire-safety systems do in fact offer protection to both buildings and their occupants.

Perhaps one of the greatest fire-safety threats of older buildings, such as "The Station" night-club, is that they can be exempt from meeting current fire-safety codes. These older buildings are often subject to "grandfather clauses", which state that a given building constructed prior to a certain date is exempt from meeting the most recent fire-codes and regulations, unless it recently has undergone a major renovation. The aftermath of the Rhode Island night-club incident, in particular, has resulted in an increase in fire-safety regulatory pressures. Soon even older buildings will be required to meet current minimum fire-safety compliance - - at least to have an adequate number of fire extinguishers and visible building exit signs.

Today, the WPI campus has some older buildings which are subject to the "grandfather clause". However, as of September 2003, WPI has proactively begun to address the fire-safety compliance of its older buildings, in the interest of acting responsibly for the well being of its educational community.

As part of this process of updating campus fire-safety code compliance, WPI has hired contractors to inspect fire-safety related equipment in all of its campus buildings. These contractors have been engaged to identify what additional effort might be needed to meet the minimum requirements of the new fire-safety codes for all WPI campus buildings. Wherever the condition of a building or its safety equipment is found to be inadequate according to the most recent fire-safety code, plans to update the safety equipment are being put into place.

Mr. Chris Salter, the Safety Manager within Plant Services, is the WPI official who maintains the records of fire-safety equipment on campus. The contractors inspecting WPI buildings for fire-safety status, have provided the Safety Manager with detailed fire extinguisher data for all of the campus buildings. This collected data indicates the location - - the building, the floor, and the room, of each identified extinguisher as well as each extinguisher's capacity, chemical type, and date last inspected. The Safety Manager is incorporating this newly collected data as he updates the current campus safety equipment records.

Our IQP project's mission has been to study the issues of building safety, focusing on fire-safety and fire-emergency equipment on the Worcester Polytechnic Institute (WPI) campus, with a goal to modernize and enhance the handling of WPI's fire-safety compliance information. The primary objectives of this project have been to:

Collect and organize Physical Plant data related to campus buildings fire-safety equipment into an electronic database. Describe the procedures needed to manipulate and maintain the database.

Create a prototype information system to utilize the database which will process and display data in a geographical form (spatial data) such as a campus map indicating fire-safety equipment locations.

Analyze the fire-safety data for four to five campus buildings and assess each building's level of risk for particular safety hazards relevant to the types of data collected. Rank each building according to its relative level of risk.

Recommend ways and means to improve campus fire-safety as well as improve the developed information system, based on the data analysis outcomes.

During the course of our project, two products have been produced: 1) a building fire-safety risk assessment report and 2) a fire-safety information system, known as CRISIS - - Campus Readiness Identification for Safety Information System. By analyzing collected available campus fire-safety data, we have prepared a fire-safety risk assessment for each of four or five buildings on campus, each ranked according to its relative safety risk. This assessment is reported below in Appendix A. The CRISIS safety information system can be demonstrated upon request.

Prior to our IQP project, no all-encompassing model of the campus layout linking building fire-safety equipment to its location within a given building has been available to Plant Services. The maps previously being used have been paper-based copies only, which are not necessarily accessible at a building location nor are readily updateable. Each time a change in campus fire-safety equipment is made, the laborious process of generating a new set of updated documents to annotate its specifics and its location has been needed.

The CRISIS system introduces electronic maps to the campus safety change process, which enhances and streamlines the change process considerably, providing improved data accuracy and providing more timely distributed safety equipment location updates.

By collecting the available fire-safety information records and organizing them into an electronic database, the safety information is made available in a spatial context for computer processing. Through the use of selected Geographical Information System (GIS) software, our safety data can be used to produce meaningful visual geographical records and layered electronic information displays. Prior to the introduction of our CRISIS system, campus fire-safety data could only be recorded and displayed. With our project's new safety system, in addition to maintaining the capability of recording and displaying information ( although now it is handled electronically), spatial safety data can be processed and analyzed, and used in conjunction with additional captured spreadsheet and autoCAD information.

A user of our CRSIS system is able to identify each piece of campus fire-safety equipment in the context of its captured physical location. For example, fire-safety equipment can be seen at its location and relative to other safety equipment within a given building. This capability will aid the safety inspectors, as well as Plant Services and contractors who repair and maintain the fire-safety items. Our CRISIS system will save time by adding flexibility to the safety maintenance process, and may eventually reduce the quantity of paperwork needed for fire-safety documentation.

Finally, our CRISIS system allows for a commanding visual inspection of safety compliance which should reassure the fire inspectors that the WPI community is both serious about supporting fire-safety with technology and is adequately prepared for fire-emergencies on campus.

# 4 Background

Our project team of four WPI students selected safety as the area to study for this IQP project. To set the stage for this project research, we first looked at the meaning of safety. The word "safety" was typically defined as "the condition of being safe from undergoing or causing hurt, injury, or loss." (www.webster.com). In the author's words, to be safe is to assure the well-being of life and the protection of property.

We prepared for this project effort by researching publications pertaining to "general safety and emergency preparedness", and soon realized that the scope safety issues was quite vast. Given our limited resources of time and personnel, we knew we had to narrow the project scope.

During this early exploration period, the project team had several discussions with project advisors: Professor Guillermo Salazar (Civil Engineering) and Professor Fabio Carrera (Global Studies Program), and with Mr. John Miller, Director of Physical Plant, with the aim of better focusing the scope of the project.

In meetings with Mr. Miller and with Mr. Chris Salter of Plant Services, the team looked at various aspects of safety on campus. From a legal standpoint, the team considered what building renovations would be needed to comply with the most recent safety codes. We also considered needed building modifications for safety code compliance from the point of view of risk-management. Through the course of several of these group discussions, we were able to narrow our area of project study from safety in general, to campus safety, to WPI building safety, then finally to WPI building safety and building fire-safety equipment.

In light of the definitions of safety, we took building safety to mean the well-being assurance of people in and around a building when it is occupied, and the application of protective measures to keep the building and its contents safe from destruction, whether or not it is occupied.

With this definition and a narrowed project scope in hand, the team, together with input and guidance from our faculty advisors and from Plant Services, identified areas of WPI building fire-safety equipment records which needed updating. It was mutually agreed within the project discussion meetings that collecting information on WPI campus building fire-safety items and organizing and maintaining it in an electronic format, would be taken on as tasks of this IQP project. Data Records from Plant Services on fire extinguishers, illuminated exit signs, emergency lighting, and backflow-preventers were to be collected and made electronic and organized in the effort of this project.

This background section of the IQP project report reflects the dynamic change in the project's scope which the project team has worked through, as the background perspective presented here spans from safety issues in general, to specific campus safety issues, to protective measures of campus building fire-safety.

## 4.1 Common Safety Systems

A surprisingly high level of safety can be provided by simple, inexpensive devices, and that seems to be why these devices are so ubiquitous and well known to most people in developed countries. Interestingly, most of the safety devices found in public buildings today are aimed at fire-safety, these include:

- sprinklers systems
- backflow prevention
- fire extinguishers
- building exits
- fire-containing doors
- signage
- external stairs
- detectors (smoke, heat, etc.)
- alarms
- elevators

## 4.2 Building Safety Codes

In current times, building safety codes are more likely to be based on objective conclusions drawn on actuarial data, and less frequently based on intuitive experience, as they have been in the past. Today building safety codes are typically based on fire performance analysis studies. These codes are obviously a very important issue both for legal compliance, and for safety's sake. To be legal and safe, a building needs to be safety code compliant.

### 4.2.1 Building Safety Code Stipulations of Project Interest

The sections of the building safety code which are of particular interest to this project, center around requirements for fire-safety devices in public buildings. The requirements for fire extinguishers, illuminated Exit signs and emergency lighting, focus our interest to particular sections of the code. Tables are provided below showing detailed code references.

#### 4.2.1.1 Fire Extinguisher Requirements

The building safety code stipulates requirements for *travel distance* to fire extinguishers. Extinguishers for Class A, Class B, Class C, Class D, and Class K type fire hazards must fall within a maximum travel distance according to the extinguisher type. The size and rating of extinguishers must fall within the classification rating of the building and its rooms.

#### 4.2.1.2 Illuminated Exit Sign Requirements

The building safety code stipulates that illuminated Exit signs be continuously illuminated (24x7), the size of lettering to be used for the signs, and that such signs be visibly located above every building egress point in a building. Further, an illuminated Exit sign must be located wherever the direction of egress is ambiguous, such as at a juncture of corridors.

#### 4.2.1.3 Emergency Lighting Requirements

The building safety code stipulates that the floor along the building egress paths be illuminated with emergency lighting. This lighting must fall within a specific range of intensity for each individual lamp in the lighting system and that each lamp in the system have access to battery backup power. All emergency lighting systems must be tested on a known prescribed schedule.

## 4.3 The Influence of Public Opinion on Safety Measures

When catastrophic events do occur, the reported news of such events is almost always shocking and sensational, and the events are widely publicized in the media. The resulting social response is to put political and legal pressure on the local and state regulatory agencies to better respond to the needs for prevention or protection. For better or worse, governmental agencies typically respond such pressure by raising the level of required safety standards and by enforcing the requirement for inspection for compliance.

Even though media stories show live video footage of catastrophic events, the selection of these stories and the manner of their representation tends to reflect social interests rather than focus on scientifically known hazards. Thus, in terms of the information which they provide, the media is a better source for prominent political issues and inte rests, and is less reliable as a source for scientifically based hazard information.

Such media influence can cause organizations to give priority to certain prominent media-covered events. For example, in the wake of a terrorist attack, an organization may immediately launch new anti-terrorist efforts, without considering the probability of additional terrorist attacks occurring. This strategy for addressing safety concerns is very effective as a political defense because it demonstrates to the public that an organization is aware of a threat issue and is actively responding to correct the reported problem. Thus the public perceptions of the organization's safety efforts are likely to appease the majority of the public's short-term concerns whether or not the anticipated events being protected against are likely to reoccur.

On the other hand, public opinion is not always realistic, at least when compared to scientifically based safety statistics. One reason for this is that people can become accustomed to common everyday events, and in some cases, may adopt complacent attitudes toward situations that are actually quite dangerous. For example, a simple passive event like remaining sitting for long periods of time could actually be statistically dangerous to one's health; in this case, the reason being that epidemiological studies have linked inactivity with heart disease, which is known to be the foremost cause of death in the United States.

Organizations that are reviewing their safety plans are well advised to consider both the influence of public opinion pressures as well as the wealth of available scientific knowledge about likely hazards. A well thought-out safety plan should find a balance between addressing both the public's immediate concerns and the most significant statistical hazard risks.

## 4.4 Campus Safety

### 4.4.1 Academic and Scientific Contributions to Safety

Safety is important to everyone on one level or another; however, if it is merely *stated* to the public that campus safety is the highest institutional priority, only the political aspect of upholding campus safety is being addressed. The task of maintaining and *ensuring* campus safety is also influenced by scientific and budgetary considerations.

Extensive research has already been conducted on the subject of safety, and many books, papers and periodicals are published on various specific safety topics, including one periodical specific to campus safety (www.campusjournal.com). Despite the great wealth of available research and technology, the practice of safety will never been completely understood and the risk of dangerous events will never be completely eliminated. This is why safety objectives are typically focused on minimizing risk and managing the risk rather than on hoping to eliminate it.

When WPI was founded in 1865, campus safety was not as big of a concern as it is today. Over the years, our campus safety has improved due to the installation of new fire-safety devices, such as exit signs and sprinkler systems. WPI has been in compliance with building codes over the years, although today it has older buildings subject to grandfather clause code exemptions. In the light of several recent serious fires, inspectors are now pushing for older buildings that may have been "grandfathered in" to be renovated so as to comply with new fire-safety standards.

Plant Services at WPI has always fulfilled the responsibility of overseeing code compliance of campus buildings and the proper maintenance of safety equipment. They check illuminated exit sign batteries, and verify that fire extinguishers are current and up to specification.

WPI has a history of interest in campus safety. A fire protection engineering department has existed at WPI for many years. Several break-through safety inventions have come out of this department, such as "the fog" fire hose nozzle, known for effectiveness in fighting shipboard fires. Further, WPI has a Safety Manager in Plant Services to focus on personal safety in the university community.

### 4.4.2 The Use of Existing Safety Literature

As mentioned above, many researchers and student project teams have gone about surveying safety topics, and have attempted to find solutions to many safety related problems.

WPI IQP project # 00E041I: "Fire Safety in Student Housing" claims that the costs of safety improvements can be paid for by the resulting savings in insurance premiums.

As within many fields, there are some very high-tech systems described within the field of safety; however, many of these systems provide what have been deemed complicated, unnecessary and expensive features. These sampled ultra-high-tech systems were inapplicable to out campus safety needs and have not been studied for this project.

### 4.4.3 Categories of Campus Safety

From the project team discussions on the general topic of safety and later on campus safety, several subtopics surfaced, and the following five were chosen to represent the key categories of campus safety:

Emergency Preparedness

Personal Safety

Environmental Safety

Occupational Safety

Property & Asset Protection

These five categories are distinct, yet they are very closely related; therefore, we have structured the study phase of the project to consider campus building safety and later building fire-safety under each of these five categories.

#### 4.4.3.1 Emergency Preparedness

For many individuals on campus, safety issues might not be foremost in the mind. The importance of safety is often overlooked until either an emergency situation presents itself and demands our attention or we are served with a fine or other penalization for not regarding safety with its proper importance. Sadly, in emergency situations, events often unfold very rapidly and a lack of preparation and preventative measures can result in catastrophe.

The word "emergency" is defined as "an unforeseen combination of circumstances or the resulting state that calls for immediate action" (www.webster.com). Emergency situations often can be averted by foreseeing certain circumstances. So while not all circumstances can be foreseen, there are many ways in which the implementation of contingency plans can help in emergency situations. On a national and international level, the results of safety research continue to add to our knowledge and understanding of how to prepare for and respond to emergencies.

Preparation enables individuals to better act immediately because they have prior knowledge of how to use equipment, enabling them to act directly and confidently on their knowledge and thus achieve successful results more quickly. Any additional experience provided by training greatly increases the likelihood that individuals will use the equipment properly and in the most effective manner when under emotional pressure.

Immediate action is very important for minimizing and containing damage, both to persons and to property. Many emergency situations unfold very quickly, so if situations are left unattended, damage can be compounded within a short time, often growing past the point-of-no-return, resulting in effects and repercussions which are uncontrollable and irreversible. The ability to react quickly to a situation simply means that more can be done to counteract the situational events.

The occurrence of many dangerous events, such as a "heart attack", or a fire, or a natural disaster, can develop within a relatively short period of time, and it's critical to emergency response to understand the speed with which these dangerous events unfold. Usually a proper quick response will significantly reduce the risk and damage caused by a dangerous event; however, there is usually very little time to properly react under such circumstances, and certainly not enough time to begin to make adequate preparations for dealing with the event. To make matters worse, the severity of many dangerous events, including those mentioned above, escalates rapidly with time. In the case of fire, damage increases exponentially with time! Victims of sudden cardiac arrest need to be defibrillated within four minutes if they are to have better-than-even odds of survival. (Occupational Health & Safety. Vol. 72, #10. Oct. 23, 2003. p.85)

It is clear that providing campus safety requires advance preparation when there is sufficient time to educate and train members of the community to respond appropriately in a crisis situation. Education and training are also necessary for people on campus to properly use safety tools in an effective manner.

Consider that most fires are small when they start. If a person is present within the first few seconds of ignition, if a fire extinguisher is available, and if the person knows how to use it, then they can respond calmly and quickly to diffuse a potentially very dangerous and damaging event. On the other hand, if just one contingent thing goes wrong during an emergency, such as a fire goes undiscovered for a long time, or an adequate fire extinguisher can not be found, or no one present knows how to use the device, then the problem becomes much worse.

Fire extinguishers can be surprisingly effective, yet a surprising percentage of people don't know how to use them. Even if there are instructions displayed that are legible to the user, precious seconds would be lost if the user must first read through the directions before using the equipment.

One can speculate that the realization of an emergency combined with the confusion of not knowing what to do are more likely to induce a highly emotional state or panic in an individual. In these circumstances, a person is likely to waste precious time by calling for help or fleeing the scene. Emergency planning and training help to reduce the related secondary problems which include mass confusion, hysteria, and panic. Otherwise, many of these natural human reactions can combine to exacerbate the difficulties of handling an emergency situation. To provide an acceptable level of protection for people and their assets, extensive emergency preparation is required.

#### 4.4.3.2 Personal Safety

Personal safety within campus buildings can be considered in two groupings: issues concerning personal security and issues concerning personal safety in the face of environmental and/or occupational hazards. In the interest of security, individuals should learn information about existing threat levels around the campus buildings and should always be aware of their surroundings, particularly noticing when anything is unusual or out of place. Many steps can be taken by the university to address personal security issues. The presence of police on campus, well lit building pathways and building parking lots, available emergency telephones, available safety escorts to and from buildings, and emergency motor vehicle assistance in parking lots, are all measures which can contribute personal security in and around campus buildings.

Personal safety in the face of environmental and/or occupational hazards on campus is a responsibility that should be shared by the whole university community; the community has a role in helping people in distress. All community members should consider how to help others in a crisis without endangering themselves, as they themselves might be in a similar situation of need at some future time.

There are no absolute rules about what an individual should do in an emergency situation, but planning ahead and thinking about the possible options available enable one to think more clearly should a problem arise.

## Thoughts on Personal Safety Areas of Study

Towards the beginning of this project, the project team considered examining the primary causes of individual fatalities as a way to get a handle on an appropriate level scope with which to study campus safety.

The graph shown in

Figure 1 below presents a graph of the reported externally caused mortalities, on a national level. The largest category reported is labeled "Other" (43%); this category mostly represents transportation related accidents. The next largest graphed category of fatalities, is labeled "Intentional Self Harm" (19%), is suicides. The third largest grouping is labeled "Assaults" (11%), followed in size by the fatalities due to falls (9%), and those due to poisoning (8%). Moving on to the smaller groupings, "Pedestrian Injuries" (4%), "Accidental Drowning" (2%), "Uncontrolled Fires in Buildings" (2%), and finally "Exposure to Inanimate Mechanical Forces" or crushing (2%).

Looking at each of these accident categories as suggested possible personal safety areas of study in this project, the project team discussed each area, then decided whether or not to pursue the area for further consideration, depending upon its "fit" with the agreed upon project focus of campus building safety.

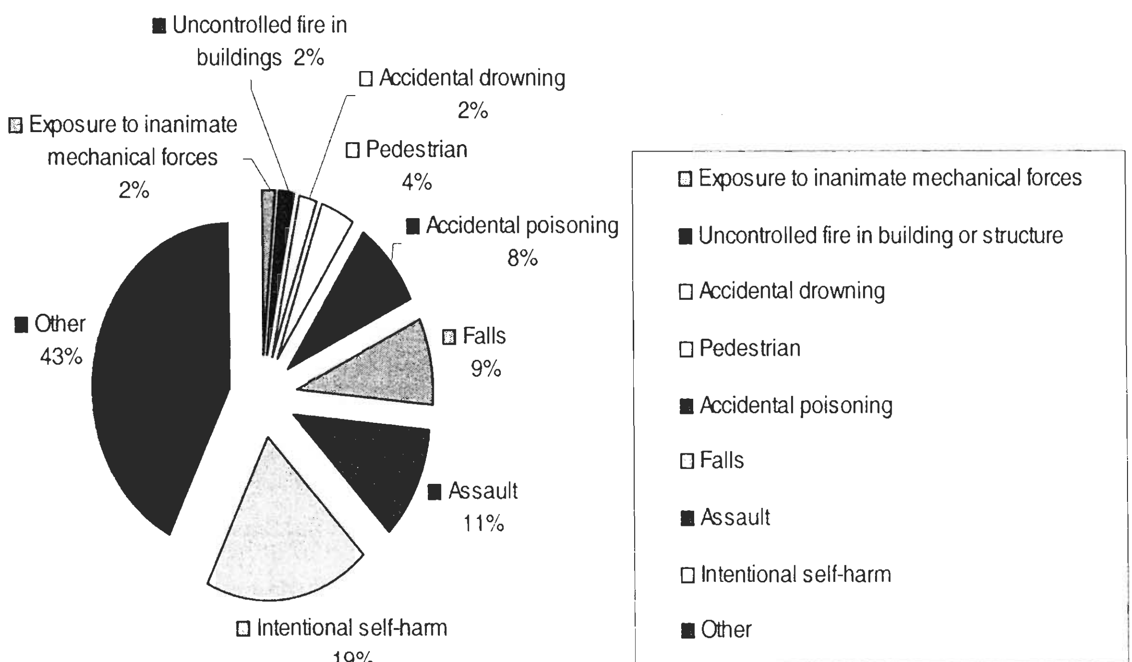


Figure 1: External Causes of Mortality (Source: National Safety Council (**www.nsc.org**))

Although the area of transportation accidents have the largest concentration of reported fatalities, these types of accidents were not related to personal safety on campus. In considering the category of suicide, it was noted that a substantial fraction of suicides occur among young people, including students. It was interesting to note that more attention on campus seems to be given to fire-safety than to suicide prevention. Why is this the case, if ten times as many people die from suicide than from fire? Perhaps this is something to consider in the future. The team decided, however, not to pursue the study of suicide for this project.

Assault prevention was discussed as an area of safety study, but it was felt that most assault related deaths probably occur off-campus so this area would not be pursued. A significant fraction of personal falls probably occur on campus, and the risk of injury caused by falls could definitely be studied in an IQP project, but the team felt that this consideration was beyond the scope of this particular project.

It was felt that many accidental poisonings were drug related. It was not known whether anything could be done within the allotted timeframe to study this category. Pedestrian injuries and fatalities are significant statistically, and it was felt that the traffic patterns of both vehicles and pedestrians could be studied in and around WPI. Other WPI IQP's are known to have obtained traffic data on a street by street basis from the City of Worcester, yet it was decided not to pursue this category for further study.

Accidental drowning was considered as a possible area of study. The WPI Master Plan indicates that WPI may get a new full sized swimming pool, since WPI's existing pool is not large enough to host intercollegiate swim team competitions. This new larger pool is likely to lead to increased numbers of pool users, which would increase the risk of accidental drowning. According to the data from the National Safety Council, this may pose a notable risk, although further study of this topic was deemed beyond the reach of this project.

The risk of students being crushed within a campus building was not considered very likely, so this area of study was not pursued for this project. Finally, the area of fire related fatalities was pursued in this project because it most closely fits the focus of this project, which is building safety.

### 4.4.3.3 Environmental Safety and Safety Equipment

Environmental safety on campus, protection against fire, gas leaks, flooding, or hazmat spills calls for prior planning and community education. Community members need to know what is expected of them in the case of such an emergency. Building evacuation plans, fire alarm locations, fire extinguisher locations should all be known in advance of a crisis. In the face of an environmental emergency situation, the roles of students, faculty, staff, employees as well as professional emergency personnel should be well understood by all the community stakeholders.

### Backflow Preventers

Backflow prevention is a very important device that helps to ensure the safety of a building's plumbing. The device is designed to prevent non-potable downstream water from mixing with and contaminating potable upstream water. They are used in plumbing situations where a there is a cross-connection in high-hazard-type facility. Facilities such as hospitals, laboratories, and car washes fall into this classification. There are basically two types of back-flow that can occur, 1) back-siphonage and 2) backpressure. Back-siphonage can occur when there is a loss of pressure in the supply line. This can be caused by a failed supply pump or a water main break. The "pressure head" resulting from the weight of the water can create a vacuum which actually sucks the contaminated water back into the potable water supply. The phenomenon called backpressure, occurs when a potable water supply is connected to a system with a higher pressure. In this situation, the non-potable water can be forced into the potable water supply (www.src4.org). The use of a properly functioning backflow preventer will prevent these types of contamination of the water supply.

The only sure way of preventing backflow of liquids is to use a backflow preventer, which is a device that is installed inline with the pipe and only allows water to flow in one direction through a pipe. The most important data for backflow preventers are the previous testing dates and their locations within buildings.

Figure 2: Backflow Preventer
(www.SensorFlushValves.com)

Backflow preventers are used at WPI in the laboratories. This allows WPI to protect the potable water supply and prevent laboratory fluids from contaminating campus drinking water. A backflow preventer is shown above in Figure 2.

## Sprinkler Systems

Automatic sprinkler systems are fire protection devices that mainly serve to slow and contain building fires, thus buying time for occupants to escape and the fire department to arrive. In some cases sprinklers can extinguish fires if the source of ignition is in close proximity to a sprinkler device. It is a commonly held belief among fire safety experts that sprinklers are one of the most important fire safety devices. The National Fire Protection Association (www.NFPA.com) claims that sprinklers reduce the risk of fire related deaths and property loss by over 50% in all types of property, also no more than two people have ever been know to die from fire related causes in a fully sprinkler-fitted building (www.NFPA.com).

The cost of retrofitting sprinklers in existing buildings is known to range from about $1.50 to $2.50 per square foot. (Fire Sprinkler Network, www.sprinklernet.org) Furthermore, the savings due to the reduced cost of fire insurance is estimated to pay for a sprinkler system in approximately 20 years (WPI project # 00E041I: "Fire Safety in Student Housing"). This is not a particularly long time given that buildings can easily last much longer than 20 years before renovations are needed. The economic justification alone strongly suggests that sprinklers are a good investment; in particular when the other advantages of improved fire safety are accounted for, sprinkler retrofitting appears to become more than just a sensible investment. If the sourced data is correct, then sprinkler retrofitting actually appears to be a savings, and the decision to retrofit sprinklers then becomes obvious, perhaps it's even foolishly risky not to retrofit!

As with backflow preventers, the most important data for sprinkler systems are the previous testing dates and their locations within buildings. Sprinkler systems are not regulated federally, only by the state government. In Massachusetts, all buildings taller than 75 feet are required to have adequate fire protection by automatic sprinklers in accordance with the provisions of the state building code. Sprinklers are exempt from certain areas in public places such as hospital patient rooms, public and private libraries and places of worship. These places have the option of having an automatic sprinkler system however they aren't required to under state law. In Massachusetts regulations can also be modified at anytime as the fire marshal sees fit (Mass Gen Law).

Figure 3 below shows five types of automatic sprinkler heads.

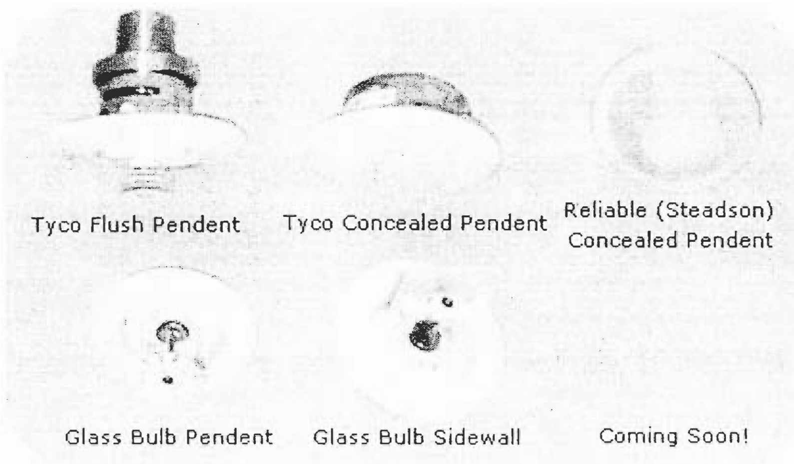


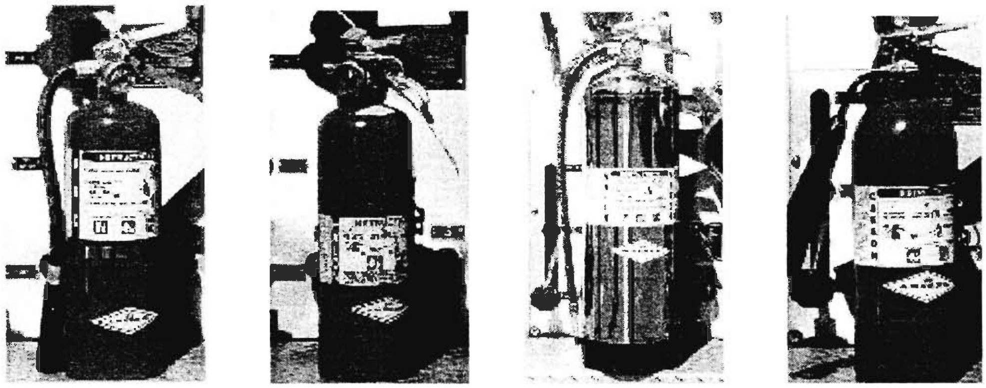

Figure 3: Types of Automatic Sprinkler Heads
(http://www.firebusters.com)

## Portable Fire Extinguishers

The presence and use of portable fire extinguishers can prevent a large number of fires from becoming more serious, however, portable extinguishers are only intended for use on small fires, not intended to attempt extinguishing large blazes.

Fire is a chemical reaction in which a material rapidly reacts with oxygen, a process known as oxidation. Three elements are necessary for rapid oxidation to occur: heat, oxygen and a fuel (some combustible material). (http://www.fs.utoronto.ca/user/files/HTML/nts-10-3873-1.html) Different types of combustible materials are classified into five common fire-types, known as Class A, Class B, Class D, and most recently, Class K fires. Similarly, portable fire extinguishers are classified according to the class of fire on which they may be used.

Class A extinguishers will put out fires in combustibles such as wood, paper, and cloth. Class B extinguishers are rated for flammable liquids such as gasoline, grease, oils, and cooking fats. Class C extinguishers are to be used on burning electrical equipment. Class D extinguishers are designed for use on combustible metals, and Class K extinguishers are designed for extinguishing kitchen grease fires.



**Dry Chemical** **Halon** **Water** **Carbon Dioxide**

Figure 4: Four Common Types of Portable Fire Extinguishers
(http://www.hanford.gov/fire/safety/extingrs.htm)

Fire extinguishers work by either cooling the burning fuel, by restricting or removing oxygen from the fire, or by interfering with the chemical reaction so the fire can't continue to burn (http://www.tech-works.com/htbin/webware/default.asp?HR=11-37&agency=stamford_city&perform=TXT).

Four common types of extinguishing substances (extinguishants) are used in fire extinguishers; each type of extinguishant is used on a given class of fire. The <u>dry-chemical</u> type extinguishing substances are used on several types of fires, such as paper, gasoline, and electrical fires. Dry-chemical type fire extinguishers can be effectively used on Class A, Class B, and Class C fires. Dry-chemical extinguishers contain an extinguishing substance and a non-flammable gas as a propellant. They have an advantage over $CO_2$ extinguishers as they leave a blanket of non-flammable material on the extinguished material which reduces the likelihood of re-ignition. Dry chemical substances make a terrible mess -- but if the choice is a fire or a mess, the mess is preferable. There are two kinds of dry chemical extinguishers: type BC extinguishers contain sodium or potassium bicarbonate and type ABC extinguishers contain ammonium phosphate. (http://www.ilpi.com/safety/extinguishers.html)

The <u>halon</u> type extinguishing agent contains a gas that interrupts the chemical reaction taking place when the fuel burns. Halon extinguishers are used on Class B, and Class C fires, but are particularly useful for protecting electrical equipment, since the extinguishing substance does not cause damage to electronic equipment and there is no residue to clean up following its use.

The <u>water</u> type extinguishers use water and a compressed gas. This type of extinguisher is used to put out Class A fires such as wood, paper and cloth, but is not suitable for class B, C and D fires such as burning liquids, electrical fires or reactive metal fires. In these cases, the flames will be spread or the hazard made greater. (http://www.ilpi.com/safety/extinguishers.html)

The carbon-dioxide ($CO_2$) type extinguisher uses carbon dioxide stored as a compressed liquid as the extinguishing substance. As the liquid $CO_2$ is released, it expands, cooling the air surrounding the fire. The gaseous form of $CO_2$ is 50% heavier than air so the gas sinks to the base of the fire to readily extinguish it This type of extinguisher is designed to be used on Class B fires (flammable liquids) and Class C electrical fires. They don't work very well on class A fires because the material usually reignites. $CO_2$ extinguishers have an advantage over dry-chemical in that they leave behind no harmful residue. (http://www.ilpi.com/safety/extinguishers.html)

## Fire Extinguisher Labels

Labeling on fire extinguishers made up of symbols and letters, provides the user with ready information as to the size and class of fire the given extinguisher is designed to put out, as well as identifies the extinguishing agent which the extinguisher contains. Classes of fires may be noted on labels with either the traditional classification symbol or with the newer pictograms. (See Figure 5: **Old Style Extinguisher Labeling Icons**

, below.)

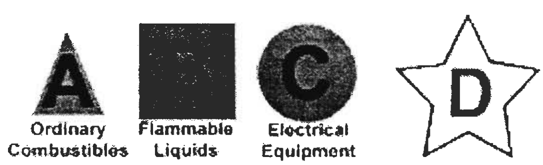



Figure 5: Old Style Extinguisher Labeling Icons
(http://www.hanford.gov/fire/safety/extingrs.htm)

The old style fire extinguisher labeling icons are shown in Figure 5. These icons on an extinguisher's label indicate a device's suitability for either Class A - - ordinary combustibles fires (a green triangle with the letter A in it), Class B - - flammable Liquid fires (a red square with the letter B in it), Class C - - electrical equipment fires (a blue circle with the letter C in it), and Class D - - combustible metals fires (a five-point yellow star with the letter D in it). Note: since Class K is a relatively new classification of combustibles, the new pictograms (See below in Figure 6) are used to represent this class rather than the older colored shape icons.

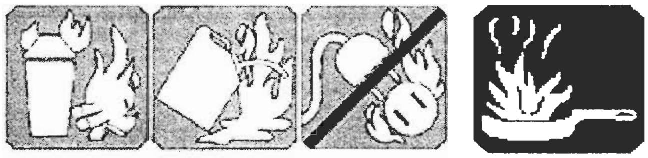


Figure 5: New Style Extinguisher Labeling: Pictograms

The new style Extinguisher labeling shown in Figure 6 indicates the suitability of a fire extinguisher device for use on ordinary combustibles, flammable liquids and kitchen fires, but not on electrical fires. (http://www.hanford.gov/fire/safety/extingrs.htm)

The size of a portable extinguisher is typically expressed on the label in either pounds of dry chemical or in gallons of liquid contained in the unit. Size is sometimes identified in the extinguisher manufacturer's model number. (http://ohioline.osu.edu/aex-fact/0690_2.html)

The rating of extinguishers is controlled by laboratory testing, either by Underwriter's Laboratories (UL) or by the Fire Marshal (FM). The higher the extinguisher's rating, the greater the capacity.

Class A extinguishers have a numerical rating referring to the amount of extinguishant the device holds and the area of fire it can successfully extinguish. For example, a rating of 1 on a Class A extinguisher means that it holds 1 1/4 gallons of water. A Class A extinguisher rated as 2, means it contains 2 and 1/2 gallons of water. The numerical rating on class B extinguishers indicates the approximate number of square feet of burning liquid that a non-expert would be able to extinguish. Class C extinguishers are not marked with a numerical rating; however, the letter "C" appearing on a Class C extinguisher indicates that the extinguishing agent being used is non-conductive. Although Class D extinguishers often have no numerical rating, they are often specifically produced for extinguishing a particular type of burning metal.

In addition to this classification labeling, some of the common fire extinguishers are also tested and UL rated by Underwriters Laboratories [see each online and/or see below].

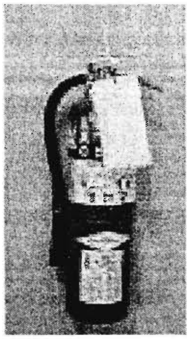


Figure 6: A Common Dry Chemical Type Fire Extinguisher (http://campus.murraystate.edu/academic/faculty/Beth.Brubaker/fire%20extinguisher.jpg)

## Illuminated Building Exit Signs

Illuminated building Exit signs (see Figure 7, below) are a less complex safety system than backflow preventers, sprinkler systems, or fire extinguishers. Exit signs are visibly located above doorways marking the building egress routes.

The general maintenance of an illuminated exit sign involves periodic inspection to insure that it is functioning properly. If a sign is not illuminated, then the lamp(s) must be replaced or the wiring repaired or replaced. If the fixture has been accidentally damaged or damaged through tampering, then it must be repaired or replaced. The battery back-up power supply must be periodically tested and fixed or replaced whenever found impaired.


Figure 7: Illuminated Building Exit Sign (http://www.allactionalarm.com/Exit%20Sign%20Hidden%20Camera.gif)

The most important information to know about these devices is whether or not they have battery backup, and if they do, how old the batteries are, and when they were last tested.

#### 4.4.3.4 Occupational Safety

The goal of occupational safety is to provide safe working conditions for all the campus community members. The OSHA organization publishes workplace safety guidelines and site safety compliance inspections to promote occupational safety.

The business of campus occupational safety is keeping students, staff and faculty safe. Injury prevention primarily depends on the recognizing workplace hazards and maintaining a safe work attitude within the community.

#### 4.4.3.5 Property and Assets Protection

The protection of equipment, material property, and Institute assets at WPI is handled by both commercial insurance protection, disaster preventative planning, and emergency situation monitoring. Lines of insurance are purchased for protecting property from such perils as fire, hurricanes, and lightning. Smoke, fire, and gas leak alarms are monitored for activation, giving rise to quick emergency response which protects material property. Further, in-house disaster preventative programs are developed and updated to attempt to nip emergency situations in the bud, before material destruction can become significant.

### 4.4.4 Fire-Safety on the WPI Campus

There are many aspects of safety that campus personnel are concerned with; however, fire-safety is preeminent because of the significant personal damage and enormous property destruction that a large fire can cause in such a short time. Fire-safety is very significant because it impacts every other mentioned category of campus safety.

The chart below (see Table 1) illustrates the importance of fire-safety within each category of campus safety considered above. The five campus safety categories are listed with fire-safety liabilities indicated for each category.

| Category of Campus Safety | Key Safety Factors to Address Fire Emergencies |
|---|---|
| Emergency Preparedness | Alarms<br>Building Evacuation Plan<br>Marked Building Exits<br>Available, Non-Expired Fire Extinguishers |
| Personal Safety | Control of Accidental Exposure to Toxic Gases, Burns, Hazardous Materials |
| Environmental Safety | Containment of Fire or Hazardous Materials<br>Guard Against Groundwater Pollution |
| Occupational Safety | Absence of Workplace Hazards<br>Presence of Personal Safety Equipment<br>Community with Careful and Non-accident Prone Attitude |
| Property and Asset Protection | Guard Against Loss of Property Due to Fire, Water Damag and Theft |

Table 1: Key Fire-Safety Factors which Impact Each Campus Safety Category

#### 4.4.4.1 History of Fire-Safety Record Keeping by Plant Services

Plant services produced information pertaining to prior methods for tracking and cataloging fire extinguishers. The first tracking method was a simple spreadsheet, which showed all the extinguisher information about each individual extinguisher. The next tracking method used by plant services utilized a bar code system. In this system a unique bar code was placed on each individual extinguisher. This system used Protrac Fire & Safety 8.00 software to track and record the inspection and maintenance of fire extinguishers. The system was the most extensive system used by plant services. Problems with it were that the fire inspector wanted to see physical tags with hand written signatures on the extinguishers, and it was too expensive to have personnel to run and maintain the system. Due to the high cost and time required to maintain the tracking system plant services found it to be more economical to hire an outside contractor to maintain the campus fire extinguishers.

WPI contracted a company named "O'Connell" to replace all of the fire extinguishers on campus. To reduce maintenance costs, O'Connell installed the minimum number of fire extinguishers possible, while still remaining code-compliant.

WPI now relies on contractors to maintain all of the fire-extinguishers on campus, and to ensure that the equipment complies with the fire-codes according to state and federal laws.

### 4.4.5 Importance of the E-Safety and E-Campus Initiatives

The E-Safety project and the E-Campus initiative have become important topics at WPI for several reasons. First of all, new technologies have introduced new safety products, and new tools for managing building safety systems and handling their associated information. As experts continue to study building safety, more is understood about what is safe and what isn't. Sometimes this knowledge is passed directly to the public, but too often it takes a tragic accident to occur before the public becomes truly aware of the importance of safety precautions.

### 4.4.6 Computerized Systems and Software-based Tools Available for Safety Studies

Electronic documents, spreadsheets, and database systems are commonplace tools today for capturing and manipulating any data of interest. The most basic use of electronic data involves one or more of these tools.

For creating and maintaining electronic engineering drawings, Computer Aided Design (CAD) systems are a standard in use today. These systems involve working with hardware, software and specialized data.

Geography and the data describing it is part of our everyday lives. Common safety decisions we make are often constrained by geographical factors. For example, when a fire is reported, we want fire trucks to respond by taking the fastest routes available. This and other aspects of fire-safety require geographic or spatial input.

Geographical Information System (GIS) software, introduced in the 1980s, are a promising tool for studying safety data. These GIS systems combine hardware, software, geographic data, and personnel to capture, store, update, manipulate, analyze and display many forms of geographic referenced data. In a simplified sense, these GIS systems are database systems designed to work with spatial data.

Software such as spreadsheets, statistical packages, and drafting packages handle simple geographic or spatial data. Databases allow for only non-spatial queries yet GIS systems allow for spatial queries, allowing for spatial operations to be performed on the data. For example, one can query a safety-equipment database for the number of fire extinguishers contained in a given building or on a particular floor in a building, but to query for something like the access coverage of a given fire extinguisher in a building, that is, the area over which a person can readily access a given fire extinguisher, a GIS system is needed.

A GIS system is applicable to this project, and a safety-equipment database could be used to model safety coverage in campus buildings.

# 5 Methodology

The methodology followed for carrying out this project can be highlighted by four key steps:

Collect fire-safety equipment data and organize it into an electronic database.

Develop a computer-based information system to manipulate and maintain the collected data.

Assess the data within the computerized information system, to evaluate the fire-safety risk of campus buildings.

Formulate ways to improve fire-safety for campus buildings, based on the data analysis with the computerized information system.

Helping to maintain safety on campus was a primary outcome objective of our IQP project. The team felt that this project approach was consistent with WPI's philosophy of the IQP (http://www.wpi.edu/Academics/Depts/IGSD/IQPHbook/). By improving the availability of, access to, and maintenance of campus building safety data, our IQP project would be contributing toward establishing a safer campus for the WPI community.

As mentioned in the Background section of this report, our team began this project by researching the topics of safety, campus safety, and safety in and around WPI campus buildings.

Following an introductory phase of general research, the project team moved to study the fire-safety equipment in buildings on campus and collect fire-safety documents from Plant Services.

## 5.1 Step 1: Collect fire-safety equipment data and organize it

In light of limited project resources, the team constrained scope of the data collection to a sample of five campus buildings, Kaven Hall (KH), Salisbury Labs (SL), Washburn Labs (WB), Higgins Labs (HL) and Goddard Hall (GH).

### 5.1.1 Acquiring Building Safety Data

The data collection task was critical to the success of our project, since the later data analysis and conclusions coming from this effort were to be based on the extent and the quality of the collected safety data.

Three types of campus safety device data were collected; portable fire extinguishers, illuminated exit signs, and emergency lighting. Mr. Chris Salter, the Safety Manager of the Plant Services

Department, manages several aspects of safety at WPI, including fire-safety equipment in campus buildings. It was Mr. Salter who assisted the project team in obtaining most of the fire-safety equipment data needed to build an electronic database.

The most recent Plant Services records for campus fire extinguishers was originally created by O'Connell Fire Protection Services, the safety company currently under contract with WPI to maintain all of the fire-extinguishers on campus. O'Connell insures that portable fire extinguisher equipment complies with fire safety codes according to state and federal laws.

In addition to safety device data, the team was given copies of the plant services building floor-plans for five selected buildings on campus. These plans did not include any system for identifying individual emergency-lights, illuminated exit signs, or any type system for tracking maintenance of these safety devices.

Detailed data for the illuminated exit-signs and emergency lighting buildings, which indicated the battery size and the date last tested, was obtained from a WPI electrician and an electrical contractor, both made available through Mr. Salter.

The fire-extinguisher records given to the team consisted of a numbered list of extinguisher devices, indicating their weight-capacity, type, and general location within a building. The data format of this equipment list was a Microsoft-Word document.

The data Plant Services had captured on these devices consisted of device identification, device description, device status, and approximate location. Different types of information were recorded for each type and unit of safety equipment. For example, the identified fire extinguishers (see Figure 4) had information records pertaining to their type, weight, and general location. The illuminated exit-signs records indicated the battery size and the date last tested.

### 5.1.2 Buildings-Survey for Verification of Fire-Safety Equipment Data

Using the information obtained for the current fire extinguishers on campus, a survey was conducted using a print-out of the floor plans. The plans were verified by walking through the buildings and verifying that the equipment was in place. Any errors found in the plans were corrected. The location of each extinguisher was mapped by marking its location on the plans. The plans were marked up by hand for Washburn, Goddard, Kaven, and Salisbury; all of the buildings except for Higgins. The emergency lights for Higgins are hardwired into the normal lighting system, which means that the locations of the emergency lights are not visible. For Higgins, all the exit signs were mapped out by visual inspection. The "as-builds" electrical plans for Higgins were needed to find the location of the emergency lights. Plant serviced was contacted to obtain the "as-builds", but the plans were never received.

After the buildings survey, an updated electronic spreadsheet was created for tracking all of the information that was obtained for each piece of equipment.

Following the collections of copies of the safety equipment and floor plan documents from Mr. Salter, the team conducted a field survey of five selected campus buildings. The purpose of the survey was to validate the paper recorded information by comparing the equipment list with the actual devices. Each piece of safety equipment was located in its building according to its identification number on the list, and the device was checked for its precise location. A new record was made containing the precise location data.

The survey was conducted by asking each one of the team members to walk through one or more of the five campus buildings with a copy of the Plant Services records for the appropriate building. Then the indicated room or hallway was checked for the exact location. The exact location of each safety device was noted by drawing a symbol for the type of device on a printed copy of the architectural floor plan for the given building. For each itemized piece of equipment, the record of its general location was used to find the room containing the device. Then the room was searched for the device and thus the actual location of the piece of equipment. Once located, a record of the exact location of the device was mapped by drawing a symbol on a printed-copy of the architectural floor-plan.

This validation step insured that the data targeted for our electronic database was accurate and was suitable for further study. At this point, the team had obtained both a data record and a corresponding mapped location for each piece of equipment. During the course of this survey, a few inconsistencies in the records were observed, and were noted for later corrections to the database.

### 5.1.3 Developing an Electronic Safety-Equipment Database

Our aim in creating a safety equipment-systems database was three fold: 1) to be able to improve the timeliness and accuracy of the current campus safety equipment record-keeping process, 2) to streamline the current process of updating equipment data, and 3) to provide insight to this project team needed to formulate informed recommendations on how to improve fire-safety in WPI buildings.

We wanted the database structure to support the ability to access the database for multiple uses. The data needed to be available through software objects for program reference, as well as for data-entry during the database maintenance process. To achieve these design objectives, it was necessary to make adjustments to the data format in order to support all of the database's intended uses.

In tackling the creation of a safety database, the team found that the process of organizing the safety equipment data required a substantial amount of time and effort. The three types of fire-safety devices that were studied were fire extinguishers, illuminated exit signs, and emergency lighting.

Initially, we set up our electronic database using Microsoft Access software, by entering equipment data directly into a structured database. In the process of developing a database structure, we soon discovered that it was apparent that several design revisions were needed before the database format was acceptable. Initially, the project personnel had minimal experience with Microsoft Access database software, and it was found to be quite inflexible for our exploratory work with the data schema. Since the database structure had not been accepted and finalized, we decided that it was inefficient and risky to proceed with the extensive manual data entry into the apparently rigid structure of a Microsoft Access database.

To develop a "best fit" data format, we tried entering the data into a Microsoft Excel spreadsheet prior to entering it into the Access database. The team personnel were more familiar with MS-Excel, and we found that the flexibility and workability of the spreadsheet application allowed us to quickly and easily adjust the data organization and formatting. This two-stage data-entry approach was adopted for the remainder of the database population.

By converting the paper-based records of the safety-equipment data into an electronic format, this project has considerably modernized the campus safety system and improved the record-keeping productivity.

## 5.2 Step 2: Develop a Computer-Based Information System

Our project team had several meetings to discuss the future plans for the safety database. To make a meaningful project contribution, we agreed that we needed to develop a set of computerized tools to work with our safety data. Plant Services requested that we update their CAD drawings showing floor plans of campus buildings with our validated equipment data. Professor Carrera urged us to take advantage of the spatial processing capability the MapInfo Graphical Information System (GIS) software. In light of these project needs, the team designed to build an information system based around our MS-Access database, with its MS-Excel front-end. The spatial mapping capability consists of AutoCAD drawings and a MapInfo GIS system. These data formats and software tools improve the efficiency of handling safety information and verifying fire-code compliance.

### 5.2.1 Computer Aided Design (CAD) Drawing Revisions

As mentioned, Plant Services expressed an interest in having their campus building CAD drawings updated and augmented by the validated data in our new database. The prior CAD drawings on file were somewhat outdated and non-standardized. Andy Strzepek mechanical engineering student on our team is familiar with AutoCAD software and CAD drawing standards. Andy offered to standardize each CAD drawing in this process, by selecting suitable line types, updating the CAD title block, and making several other updating improvements. Andy also entered a CAD object for each piece of equipment in our database.

The team developed and standardized a unique symbol and for each type of safety equipment. For each piece of equipment, a unique code was defined and used on the CAD drawings to indicate the equipment type, and the building in which it is located.

For consistency, the data displayed on the CAD drawings, uses the same symbols as used by the equipment maintenance contractors. Through this simple practice of standardized conventions, we have facilitated the cross-referencing of equipment across contractor records, CAD drawings, databases, and GIS tables.

### 5.2.2 Current System of Fire-Safety Equipment Maintenance and Record Keeping

As of 2004, O'Connell is still contracted to maintain all of WPI's fire-extinguishers. To track the extinguishers, O'Connell uses a simple list that shows the type and location of the extinguishers. The extinguishers are simply identified by a consecutive "serial" number; they do not employ a special code system to define each extinguisher.

### 5.2.3 Standardization of the Computer Aided Design (CAD) drawings

Upon initial inspection of the CAD drawings of the floor plans for each of the five buildings, it was noticed that the drawings did not adhere to any sort of standards. This meant that there were several inconsistencies in the format for each drawing.

It was recognized that the drawings did not use any type of industry standard title block. By not using a standard title block it is difficult and sometimes not possible to know the correct scale of the floor plans in regards to the sheet size that the drawing is suppose to be plotted on. Tracking changes and the origin of a drawing can be difficult or impossible to accomplish on a non-standard title block. Before any information was entered into the CAD drawings some basic standards were drafted, and a standard E-size title block was created.

An E-size title block was used because it is standard for architectural plans to be plotted on E-size sheets. The standard title block contains information as to who the original creator of the drawing was and a place for tracking revisions to the drawings. Other information on the title block is the scale of the drawing, the drawing title and description, a place for the drawings to be signed off on, and a place for any required engineering seals and company logos. The title block also displays the drawing number, which is used to identify and track a drawing.

The drawing number is unique to each drawing. A six-character code was designed to identify each drawing. The first two characters in the code identifies the building depicted in the drawing. The following single-character identifies the department that drawing is for. Last is a three-digit numeric drawing number, in which the first digit identifies the building floor, and the last two digits are a unique drawing number within each department and are a sequential numbering of the drawings. Section 4.1.4 in the draft of the CAD standards discusses the numbering of drawings.

Later, when the revisions were ready to be made to the existing drawings, it was found that there was no uniformity to the line weights, scale, and text. It was also discovered that there was no way to identify what each layers represented in the drawing, since some of the layers used the default layer name that was assigned by the program when they were created. (Sections 5 through 7 in the draft of CAD standards manual discuss these issues, and list layer names that should be used in the creation of a drawing.) Having a uniform system for naming layers and a manual to refer to makes revising a drawing less time consuming.

In the CAD drawings for the five buildings, the standards were applied to the layers needed to create the objects that identify the safety devices. In some of the drawings the standards for layer-naming were applied to the layers that were identifiable. Some layers in the drawings were not easily identifiable and for that reason they were not changed or renamed.

### 5.2.4 CAD Revisions and Equipment Codes

Once some of the basic CAD standards were implemented, the revisions to the drawings were started. For the fire extinguishers, a triangle with the extinguisher number inside the triangle was designated, as the symbol representing a fire extinguisher. A layer was created for the extinguisher in correspondence to the CAD standards that were drafted. The extinguisher symbol was created as a block named EXTIG with an attribute being the extinguisher number. Red was chosen for the line color of the symbol to make the symbol stand out in the drawing. The locations of the extinguishers were then plotted on each of the CAD drawings, using as a reference the drawings that were marked up by hand showing the locations.

For the exit signs, a symbol was used that is used throughout the building industry to identify exit signs. The symbol created for an exit sign was a circle with an x in the center. This symbol was created as a block named EXIT and the line color of red was chosen. Referring to the marked up drawings, the location of each exit sign was plotted on each of the floor plans. For identifying the exit signs a simple code was created that is unique to each building. For example the code E15-GH, the E identifies the object as an exit sign, the 15 is a two character numeric code, which is unique to each building, and the GH is the code for Goddard Hall used by WPI plant services. The two character numeric code is a sequential numbering system starting from the first floor and working up to the top floor. Using a leader made the tags for the exit signs, the codes are not attached to the blocks as attributes.

It was discovered when the entering the exit signs into CAD that the disks provided were not current. The floor plans in CAD did not mach some of the printed floor plans that were marked up with the locations of the exit signs and emergency lights. Plant Services was then contacted and it was confirmed that the files provided were not current. The current CAD drawings were found by Plant

Services and furnished for revisions. All the revisions made to the CAD drawings up until this point needed to be redone on the new CAD files.

Working with the new CAD files, the emergency lights were to be entered into CAD. The industry standard symbols for emergency lighting were used, and the symbols created as blocks in CAD. For double-head emergency lights the block was named DBL, and single head emergency lights were named REMOTE-HEAD. The line color purple was used to represent these items on the plot. The blocks for a double-head light with an exit sign were named EDBL, and for single head ESIG. A line color of red was chosen for these. The location of the emergency lights was then entered into each CAD drawing according to the locations marked out on the plots. A code to identify each emergency light was then created, which used the same format as the one used to identify the exit signs. In the code the first letter identifies the type of light; a "D" stands for double-head light, and an "S" stands for a single head light. An "E" placed before the "D" or "S" signifies that the lights also have an exit sign. The codes were then place in the CAD drawings using the leader function.

All of the CAD drawings for the five buildings were placed onto the new standard title block. The current WPI logo was then inserted into the designated spot on the title block. Scales for the drawings were then set and the scales where placed onto the drawings. The required information about the drawings was then entered into the appropriate field on the title block. For the safety equipment drawings, in addition to the colors used for the devices, the room numbers were made green, doors cyan, and stairs red. The rest of the lines used to represent the layout of the floor were changed to black. This made the location of the devices on the plot easier to identify.

The floor plans for each building were then originated to the world coordinate system, which would place them in their location on earth. This was down by using a campus map made by Judith Nitsch Engineering of Boston, Massachusetts. Each floor of the five buildings was brought into the map, and then oriented to the building footprint that was shown on the map. Before the building floor plan could be put into the proper location on the map, the floor plans need to be scaled down. This was because architectural drawings are drawn using units of feet, and civil drawings are drawn in units of inches. Once the floor plans were scaled down they were then aligned with the appropriate building footprint on the map. In aligning the floor plans to the footprint it was discovered that the drawings did not lineup correctly. The Judith Nitsch firm was then contacted to try and solve the problem. After speaking to Paul Roy the engineer who created the drawing he assured us that his drawings were correct. He also made sure that the correct scale was used to scale the floor plans. In conclusion he felt that there must be an error in the architectural floor plans. The accuracy of the architectural drawings could not be confirmed since the title block that was originally used does not display the name or firm that created the drawings.

The building that demonstrated the greatest amount of error was Goddard Hall. The layout of Goddard Hall has a large distinguishing angle in its center, where there was a difference of ten degrees in the angle between the architectural floor plans and the building footprint on the campus map. After calculating and comparing the square footage of both drawings, an error of one percent was calculated for Goddard Hall.

Of the five buildings studied, the newest one, Higgins fit most accurately into the building footprint on the campus map. Once the floor plans for each building were placed into the map, new drawings were created by floor, which showed only the floor plans for each building in their correct world coordinates.

### 5.2.5 Use of MapInfo Geographical Information System (GIS) Software

The information system we had developed utilized the capabilities of the Excel spreadsheet, the Access database, and CAD drawings. We next needed to introduce the capability of spatial analysis into our information system, to provide a way to test building compliance with fire-safety codes. MapInfo GIS software brought this capability to our safety information system.

GIS campus maps were obtained through Professor Carrera, from his work with other WPI GIS projects in association with the Worcester Project Center.

The CAD and GIS maps now contain the exact locations of the three types of fire-safety equipment in each of the five sampled campus buildings.

The project team used MapInfo to help visualize the safety coverage of fire extinguisher through spatial analysis of the data. MapInfo was used for analysis calculations to estimate safety performance parameters for each of the five buildings studied. Using this tool, we have mapped the area of coverage for each safety device and evaluated the code-compliance with respect to coverage for each building.

In addition to condensing the data and making it easier to read and interpret, MapInfo contains general purpose analysis tools, which can be customized as needed while processing and studying the data.

In addition to simple referencing and tabulation of the safety equipment data, it has been possible to "open" the database from within MapInfo. This means that any new changes to the database will be automatically updated in MapInfo. MapInfo is capable of importing single-layer CAD drawings of building floor-plans. The database information was then overlaid on the building floor-plans, thus producing an integrated campus map. From the analysis results, a list of suggested improvements will be generated.

This information system will assist in the management and maintenance of safety equipment and procedures by providing a visual model of the fire-safety equipment.

The GIS platform is flexible enough to be used in other WPI student projects, so it can be interfaced electronically with data that may exist in many formats. GIS is widely used, so additional data can be available to be shared over networks.

## 5.3 Step 3: Analyze the Data Within the Information System

The third step in our project methodology was to begin to use the information system and software tools to analyze the data that had been collected. Using the available data, the evaluation criteria were based on factors that are known to influence buildings safety, and on the probability of the occurrence of an undesired event, such as an equipment failure.

### 5.3.1 Data Analysis with MapInfo GIS Software

The NFPA fire-code was searched for regulations governing the three types of equipment under review: fire-extinguishers, emergency-lighting and illuminated exit signs. Fire-code, NFPA 10: 3.3.4.1, "*Standard for Portable Fire Extinguishers*" defines "Class A" fires as "Fires in ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics." (http://www.NFPA.org/). Buildings are classified by the types of materials they contain, and thus the type of fire hazard they present. Many campus buildings are "Class A" for this reason. NFPA Chapter 13.6.5 states the General Requirements for the Selection of Fire Extinguishers:

"The selection of fire extinguishers for a given situation shall be determined by the character of the fires anticipated, the construction and occupancy of the individual property, the vehicle or hazard to be protected, ambient-temperature conditions, and other factors... The number, size, placement, and limitations of use of fire extinguishers required shall meet the requirements of Chapter 5 of NFPA 10. [10:4.1]"

Table 2 below shows the spatial requirements of the NFPA fire-code.

| **NFPA 10, Table 5.2.1 Fire Extinguisher Size and Placement for Class A Hazards** | | | |
|---|---|---|---|
| **Criteria** | **Light (Low) Hazard Occupancy** | **Ordinary (Moderate) Hazard Occupancy** | **Extra (High) Hazard Occupancy** |
| Minimum rated single extinguisher | 2-A* | 2-A* | 4-A† |
| Maximum floor area per unit of A | 3000 $ft^2$ | 1500 $ft^2$ | 1000 $ft^2$ |
| Maximum floor area for extinguisher | 11,250 ft‡ | 11,250 ft‡ | 11,250 ft‡ |
| Maximum travel distance to extinguisher | 75 ft | 75 ft | 75 ft |

Table 2: Fire Extinguisher Size and Placement for Class A Hazards (http://www.nfpa.org/codesonline/nfc.asp?path=NFPA/codes/nfpa0001-0049/0017)

Some of these code stipulations were directly relevant to the data that was collected. This includes the equipment attributes such as size, type and rating. Table 2 above shows that the fire-code regulates certain spatial parameters such as equipment spacing and coverage. Data was collected for fire extinguisher weight capacity; however, the fire-code uses the rating given by Underwriters Laboratories (UL). Table 3 shows how these two ratings can be cross referenced. Alternatively, the UL rating can be identified by the equipment label.

**"Class A" Fire Extinguishers Specifications**

| guishing Agent | Method of Operation | Capacity | Horizontal Range of Stream | Approximate Time of Discharge | Protection Required below 40°F (4°C) | UL or ULC Classificatic |
|---|---|---|---|---|---|---|
| purpose/ABC dry ical (ammonium phate) | Stored-pressure | 1 to 5 lb | 5 to 12 ft | 8 to 10 sec | No | 1 to 3-A[c] anc to 10-B:C |
| | Stored-pressure or cartridge | 2½ to 9 lb | 5 to 12 ft | 8 to 15 sec | No | 1 to 4-A and 10 to 40-B:C |
| | Stored-pressure or cartridge | 9 to 17 lb | 5 to 20 ft | 10 to 25 sec | No | 2 to 20-A an 10 to 80-B:C |
| | Stored-pressure or cartridge | 17 to 30 lb | 5 to 20 ft | 10 to 25 sec | No | 3 to 20-A an 30 to 120-B: |

Table 3: "Class A" Fire Extinguisher Specifications

(http://www.nfpa.org/codesonline/nfc.asp?path=NFPA/codes/nfpa0001-0049/0017)

The unique feature of the GIS software tool allowed the spatial information in the database to be analyzed for geographic coverage as specified by the NFPA fire-code. The data that was collected was formatted and prepared for analysis of the coverage. The coverage was compared to the fire-code regulations.

#### 5.3.1.1 Translating the CAD Floor Plans into GIS

Initially, the GIS layers contained only the buildings' footprints. To correctly place the safety equipment objects in GIS, we first rasterized the floor plans, creating an image which we then laid under the GIS layers. The objects were then placed on top of their corresponding locations in the image. Unfortunately, the raster image is, by definition, not a vector graphic, so it could not be used for further analysis.

We then translated the CAD floor plans into GIS using the MapInfo tool known as the Universal Translator. The procedure to convert the floor plans was devised by a graduate student at WPI, Viren Samdadia, whose master thesis was on the interaction between CAD and GIS and interfacing the two systems.

His procedure was as follows: First, open the campus map .dwg file in AutoCAD. Then, open in AutoCAD the .dwg file for the building floor plan that you wish to add to the campus map. After opening the floor plan, keep only the layers you want to be transferred to MapINFO. Freeze all the other layers so that you only see the layers you want in the CAD drawing. Select all (located under the Edit menu) and run the Explode command (located under the Modify menu), which explodes any blocks present in the drawing. These blocks are believed to cause errors in translating CAD files into MapINFO. Take the floor which you want, copy that part of the .dwg file, and paste it into the campus map .dwg file. It is recommended you paste the floor plan somewhere outside the campus, as this allows space for rescaling and rotating the floor plan. Additionally, do not use the 'Paste as a Block' command. Converting the floor plan into a block to ease the rescaling, rotating and relocating process may create problems when it is later exploded.

Rescale and rotate the floor plan to line up with the footprint of the building on the campus map .dwg file. The floor plans we had required scaling by a factor of 1/12. Once the floor plan is sized and oriented to match the footprint, then move it to its correct location on the campus map. Do not place the floor plan on the building footprint unless it is sized and oriented correctly. Since the floor plan is not a block, reselecting it to modify it after positioning it is more difficult.

Save the composite drawing as a new file (under the File menu, select Save As). Save it as an AutoCAD 2000 drawing, as MapInfo does not recognize AutoCAD 2004 files. After translating the composite CAD file using the Universal Translator tool in MapInfo, locate the GIS layer containing the floor plan.

#### 5.3.1.2 Integrating the floor plans into GIS

Translating the floor plans into GIS merely created "polylines" from the walls; in other words, the rooms were not "regions". In order to make the individual rooms into regions, the floor plan layers were made editable, and the polygon tool was selected. Then each of the endpoint "nodes" of the polylines surrounding each room were individually selected with a pointing device, and MapInfo automatically created the regions. Once the room regions were created for an entire floor of a building, the regions were saved a layer.

To have the regions inherit the building code from the campus map, we ran Update Column (under the Table menu). This caused the room regions layer to inherit the building code value from the building which contained the particular room. Since the room numbers displayed in CAD were "frozen" to facilitate translation to MapInfo, there was no automatic way to retrieve the room numbers; therefore, the room numbers were filled in manually, using the CAD drawings as a reference.

#### 5.3.1.3 Spatial Analysis using MapInfo "Buffers"

One powerful tool in MapInfo is the Buffer tool. This allows an object to be created which surrounds another object out to a specified radius. We ran the buffer command on all of the safety equipment with various radii. For example, fire code states that the maximum distance one should have to go to reach a "class A" fire extinguisher is seventy-five feet. So around the ABC dry chemical fire extinguishers, we created a buffer of radius seventy-five feet. Similarly, the fire code says that a class B extinguisher should be within thirty feet, so buffers with a thirty foot radius were also drawn around each ABC dry chemical fire extinguisher.

Each of these buffers was given a field called "Coverage" and a value of unity to provide a number that could be counted by a function. Then, using the Update Column command, MapInfo was configured to count how many buffers overlapped each room. For the fire extinguisher devices, the coverage values were named "Safety Level" (see Figure 8). These are estimates of the safety in each room due to the proximity of fire extinguishers.

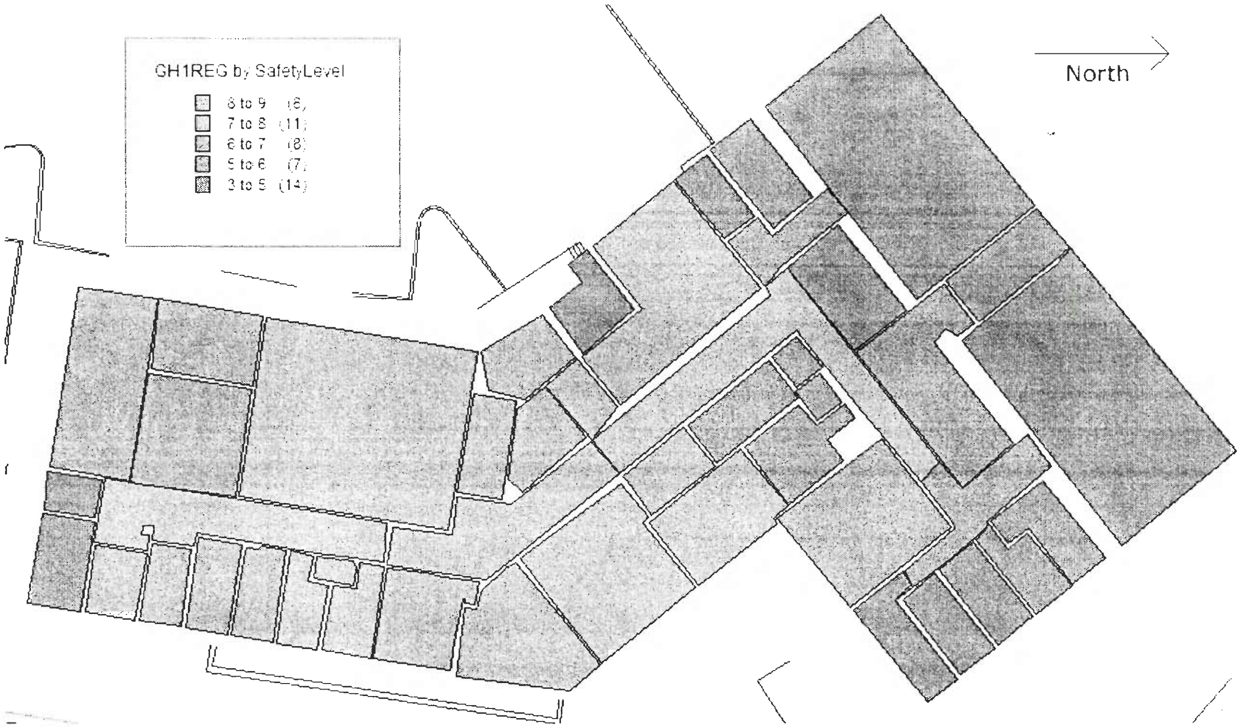



Figure 8: Map of Goddard Hall 1st floor showing the Fire Extinguisher coverage

The functions of the exit signs and emergency light devices are similar in that they are both designed to indicate the emergency egress path. There are many instances on campus where these two types of devices are actually combined into a single piece of equipment. This is why a single dataset was used to track the exit signs and emergency lights in the database, and to simplify the mapping and analysis of the equipment data.

The weighed value given to the "Coverage" field was also assigned a value of unity. This assignment was based our assumption that exit signs and emergency light devices serve equally important functions in identifying and illuminating the main egress path. The coverage values were named "Egress Safety Level". This value is an estimate of the "safety level" in each room due to the proximity of an exit signs or an emergency light (see Figure 9). In this example of the first floor of Goddard Hall, the average spacing of these devices was measured to be approximately 20 feet. Since the exact illumination level was not known, this same distance, was selected as a "buffer radius" to provide a relative measure of coverage.

The resulting calculated values are unitless parameters designed to indicate a relative measure of safety. While individually the values are meaningless, they provide a general indication of the relative safety of each room. These numbers should not necessarily be relied upon as an absolute measure of building fire risk.

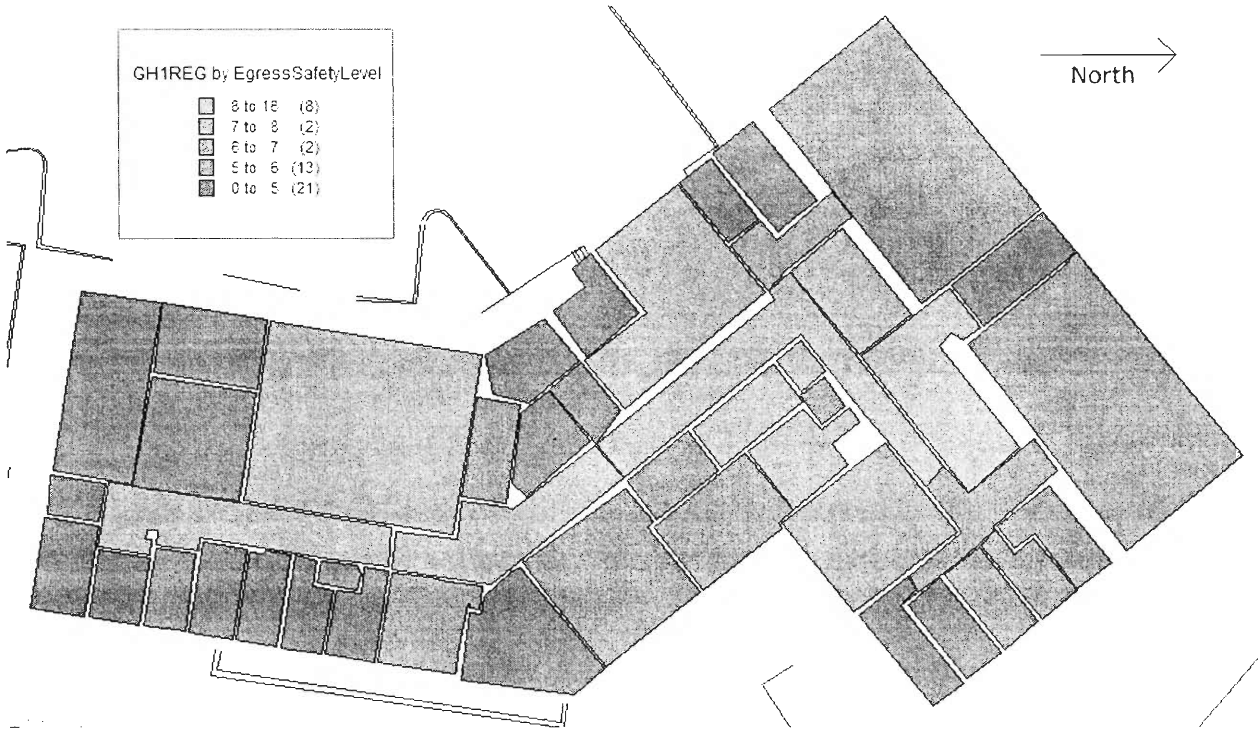



Figure 9: Map of Goddard Hall 1st floor showing the proximity to exit signs and emergency lights

### 5.3.1.4 Limitations of the Analysis method

Fire performance analysis of buildings is extremely complex and difficult to model accurately, so one must remember that the results of the analysis are at best a measure of relative safety, and they are not a measure of absolute safety. However, even with a simple model such as this, some insight is gained into the coverage provided by safety equipment,

It is tempting to try to calculate a "risk index"; however, risk analysis is very complex and is best left to the experts. The accuracy of the model is limited by many factors, including data which was not collected or unobtainable. An inaccurate calculation of a "risk index" is likely to be misleading and thus dangerously counterproductive if the results are interpreted too literally.

### 5.3.2 Step 4: Formulate Ways to Improve Fire-Safety in Campus Buildings

Despite not being able to calculate a risk-index, the basic geographic coverage of the safety equipment data can compared with the regulations and guidelines set forth by the NFPA fire-code, and the building performance may be evaluated within this context. Unfortunately, the time and resources available for this project were insufficient to complete this last objective.

## 5.4 Project Schedule

This project study will take place between September of 2003 and May of 2004. The most recent project schedule for the remainder of the project is shown in the Gantt chart (see Table 4 below).

| **E-Safety D-04 Schedule** | **March** | | | | | | | | **April** | | | | | | | | | | | | | | | | | | | | | | **May** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | T | W | R | F | M | T | W | R | F | M | T | W | R | F | M | T | W | R | F | M | **T** | W | R | F | M | T | W | **R** | F | M | **T** |
| **Task Name (Suggested Task Master)** | 22 | 23 | 24 | 25 | 26 | 29 | 30 | 31 | 1 | 2 | 5 | 6 | 7 | 8 | 9 | 12 | 13 | 14 | 15 | 16 | 19 | **20** | 21 | 22 | 23 | 26 | 27 | 28 | **29** | 30 | 3 | **4** |
| Update Project Presentation (NM) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Third Project Presentation Date (All) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Revise Intro, Background, Methodology (MP) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Establish CAD Standards - (AS) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Update CAD Drawings - (AS) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Update Database Info. - (EG) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Import CAD into MapInfo (EG, MP) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Report Results (MP, EG) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Analyze Data With MapInfo (MP, EG) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Report on Analysis (MP, EG) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Write Summary, Concl., Recommendtns (All) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Complete Draft of Project Report (MP, All) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Update Project Presentation (NM, All) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Final Presentation Date (All) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Final Project Report due (incl. CDRs) (All) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Table 4: e-Safety Project Schedule for D-Term 2004

# 6 Results

As a result from the collected data, a numbering system was developed to identify each piece of safety equipment plotted on the floor plans. The locations of the safety devices were mapped out for Goddard Hall, Kaven Hall, Washburn, Higgins Labs, and Salisbury Labs with the appropriate identification number assigned to each device. A standard title block was created, and the drawings were placed onto the title blocks.


Figure 10: CAD drawing for Goddard Hall Basement

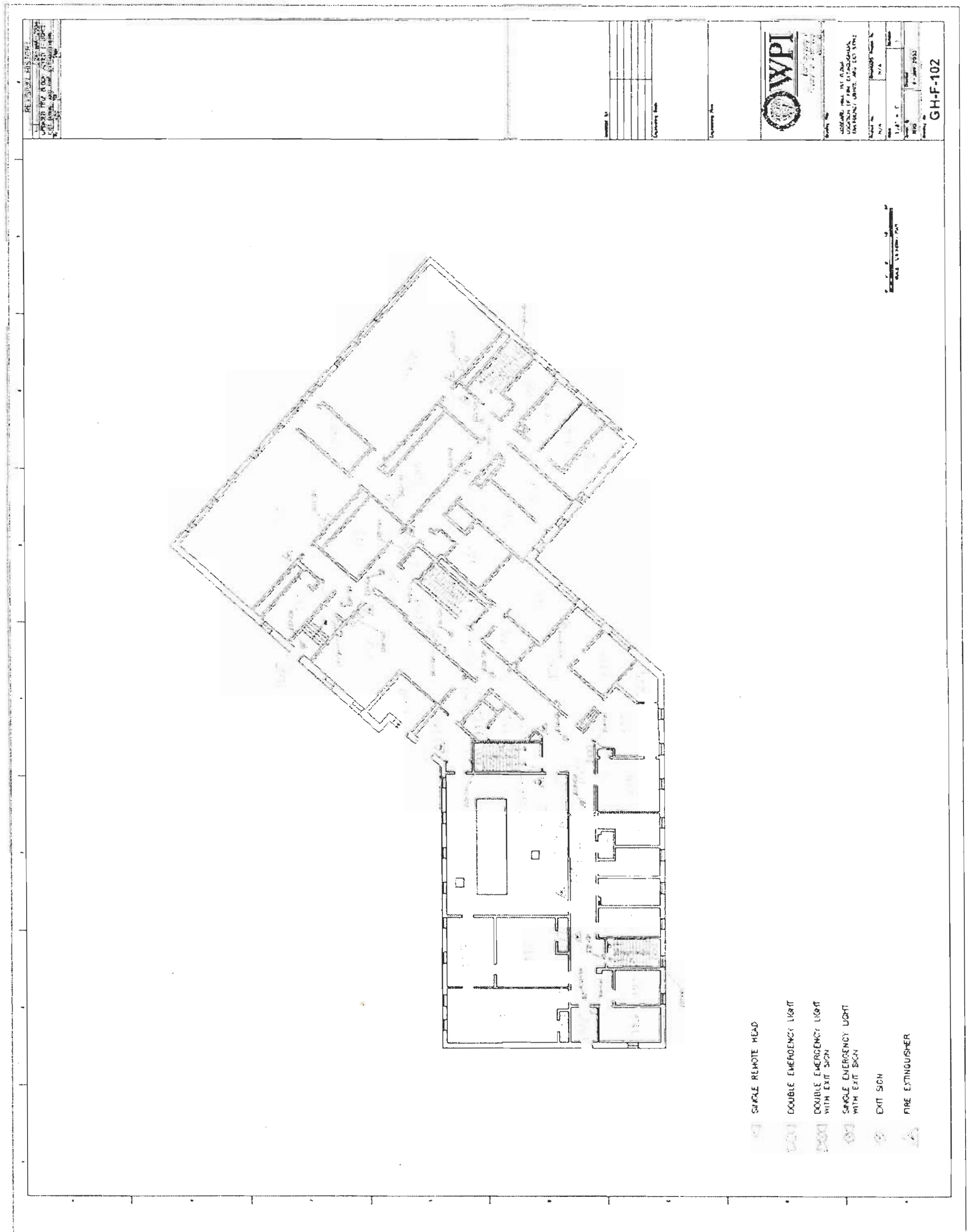



Figure 11: CAD drawing for Goddard Hall First Floor

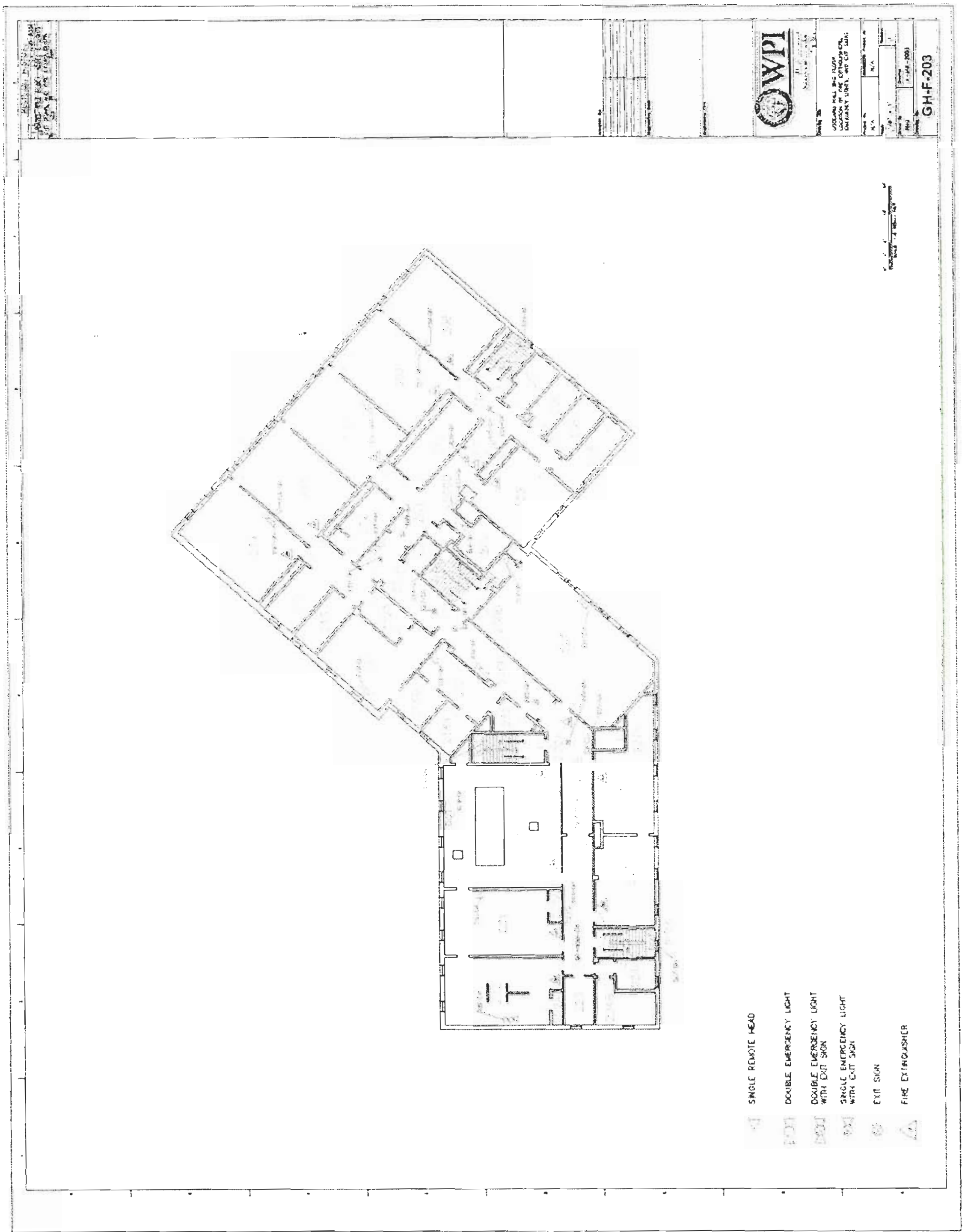



Figure 12: CAD drawing for Goddard Hall Second Floor


Figure 13: CAD drawing for Goddard Hall Third Floor

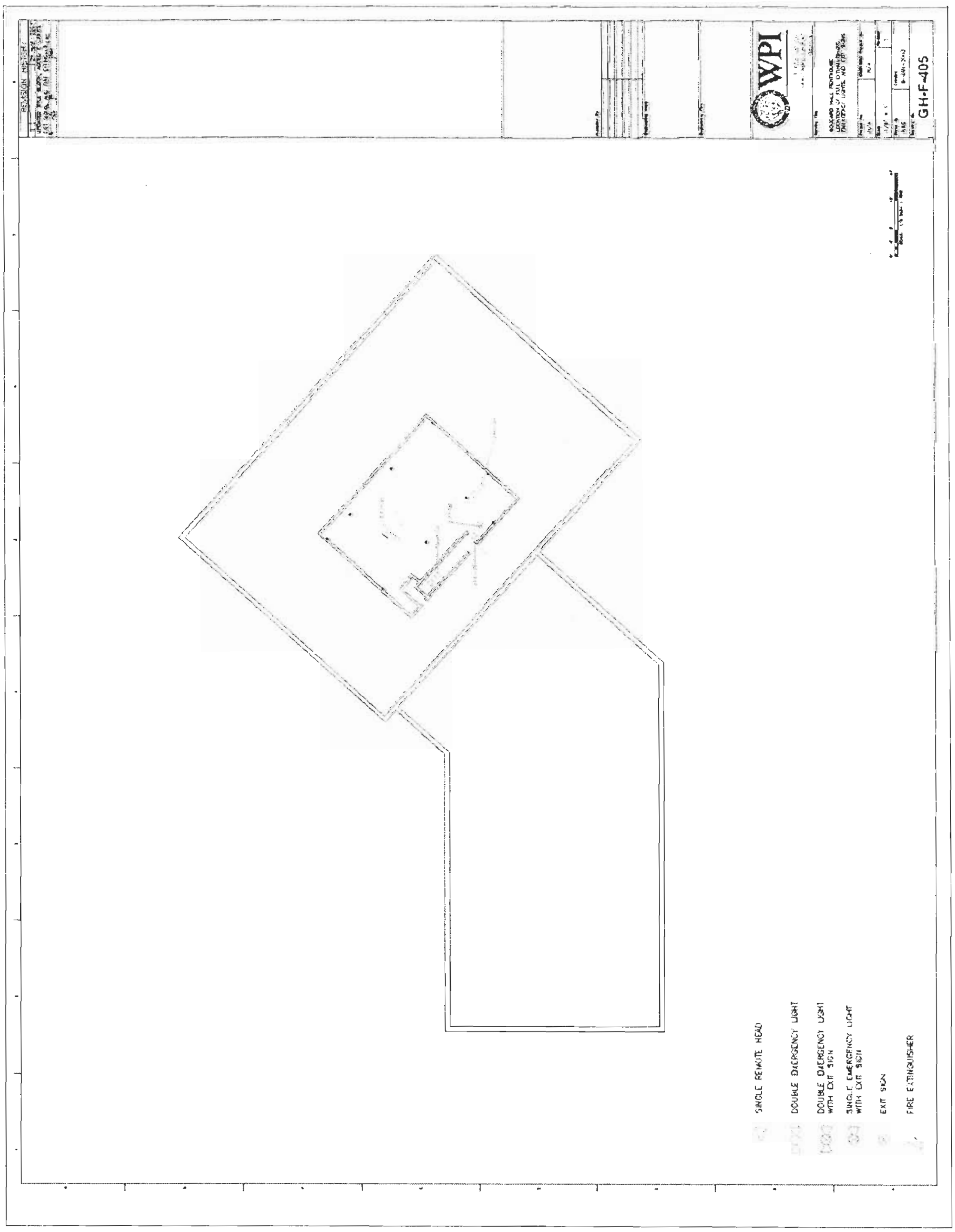



Figure 14: CAD drawing for Goddard Hall Penthouse

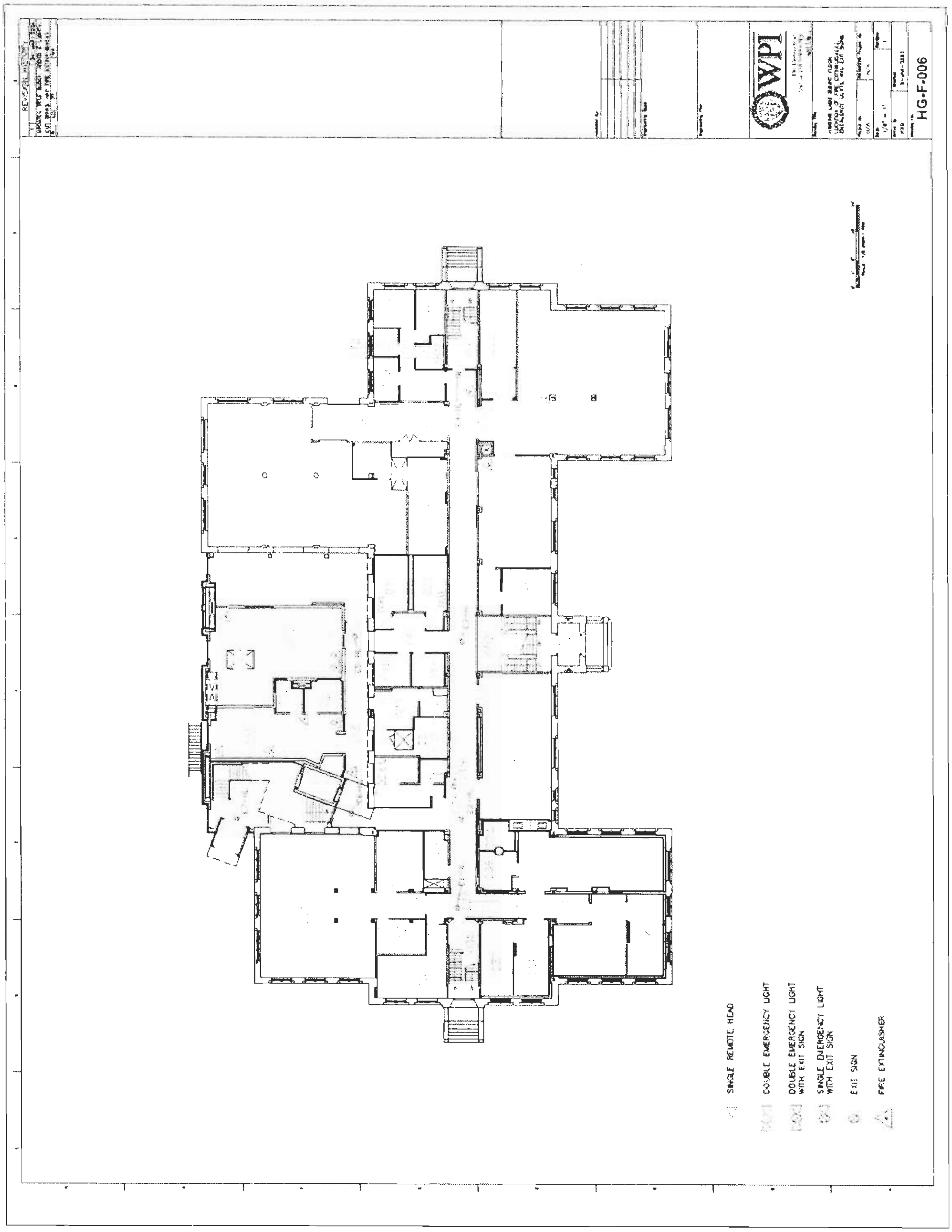



Figure 15: CAD drawing for Higgins Labs Basement

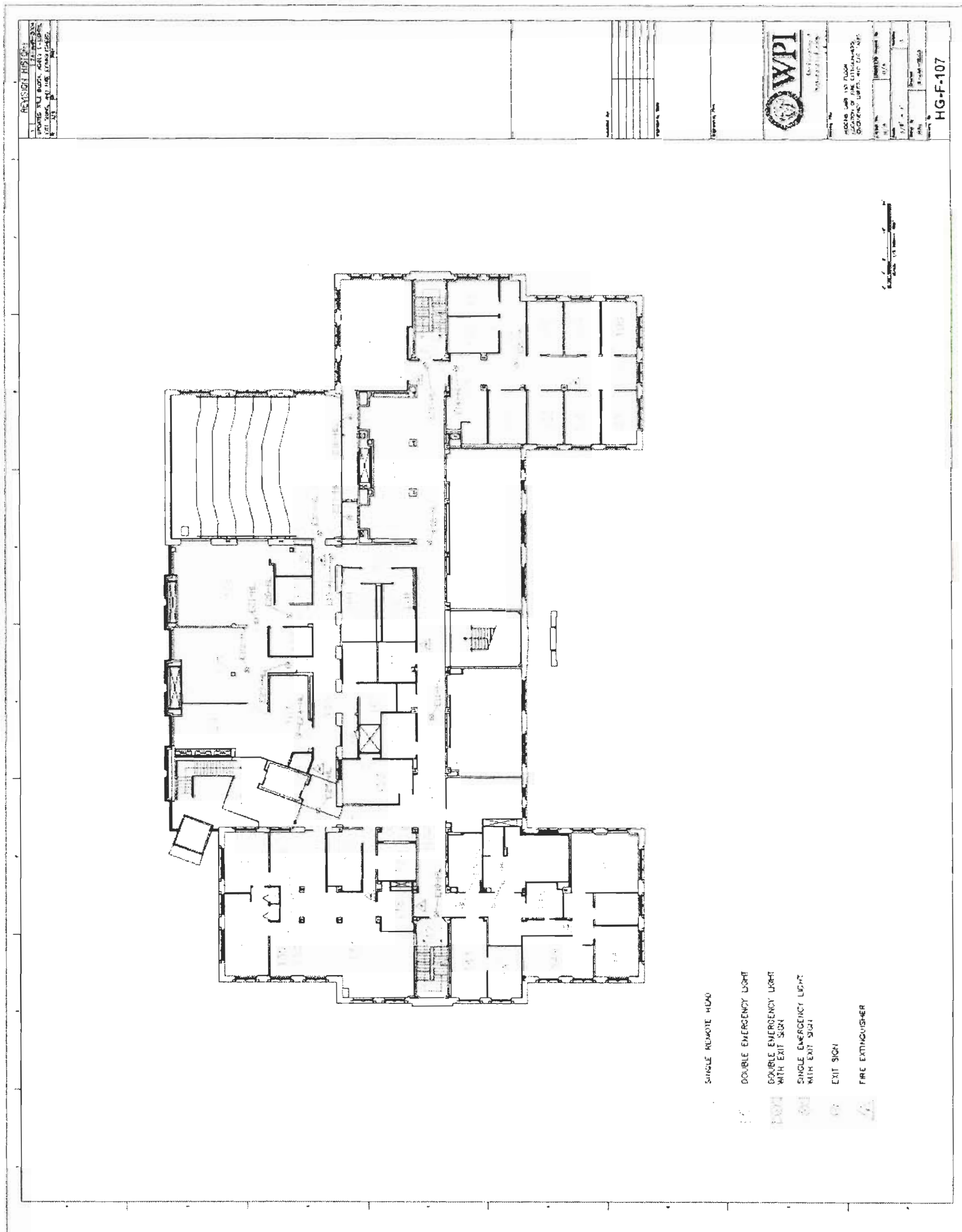



Figure 16: CAD drawing for Higgins Labs First Floor

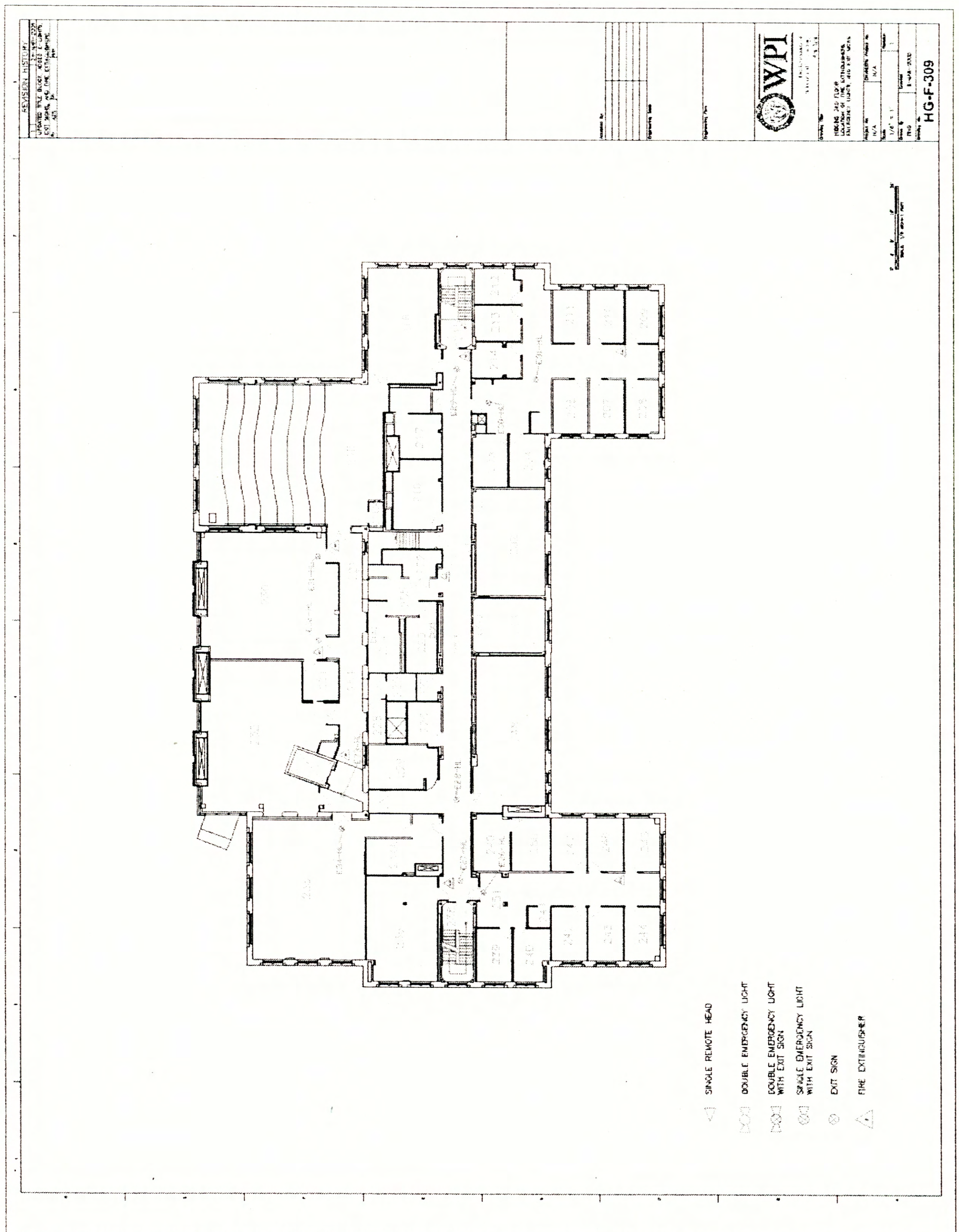



Figure 17: CAD drawing for Higgins Labs Second Floor

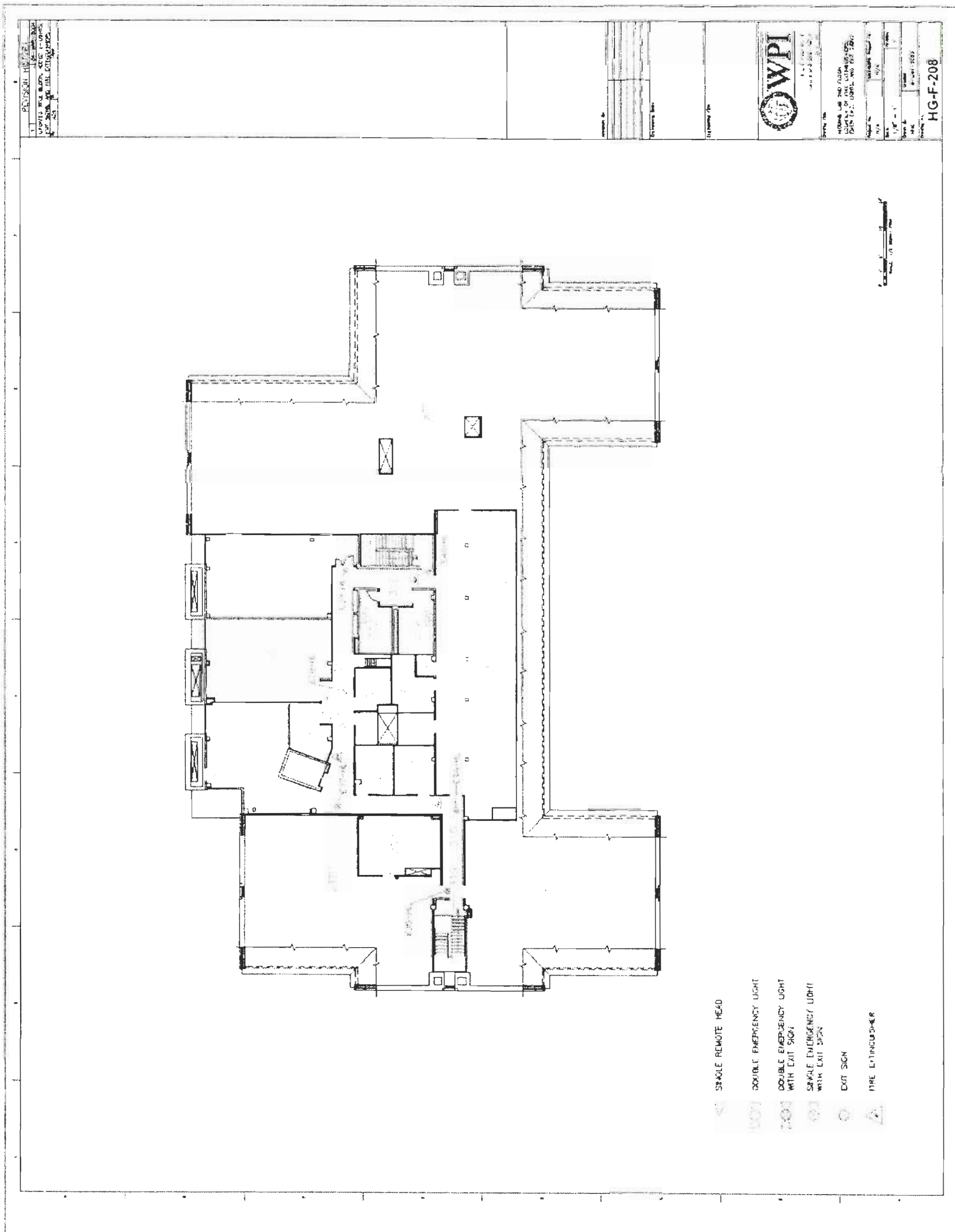



Figure 18: CAD drawing for Higgins Labs Third Floor

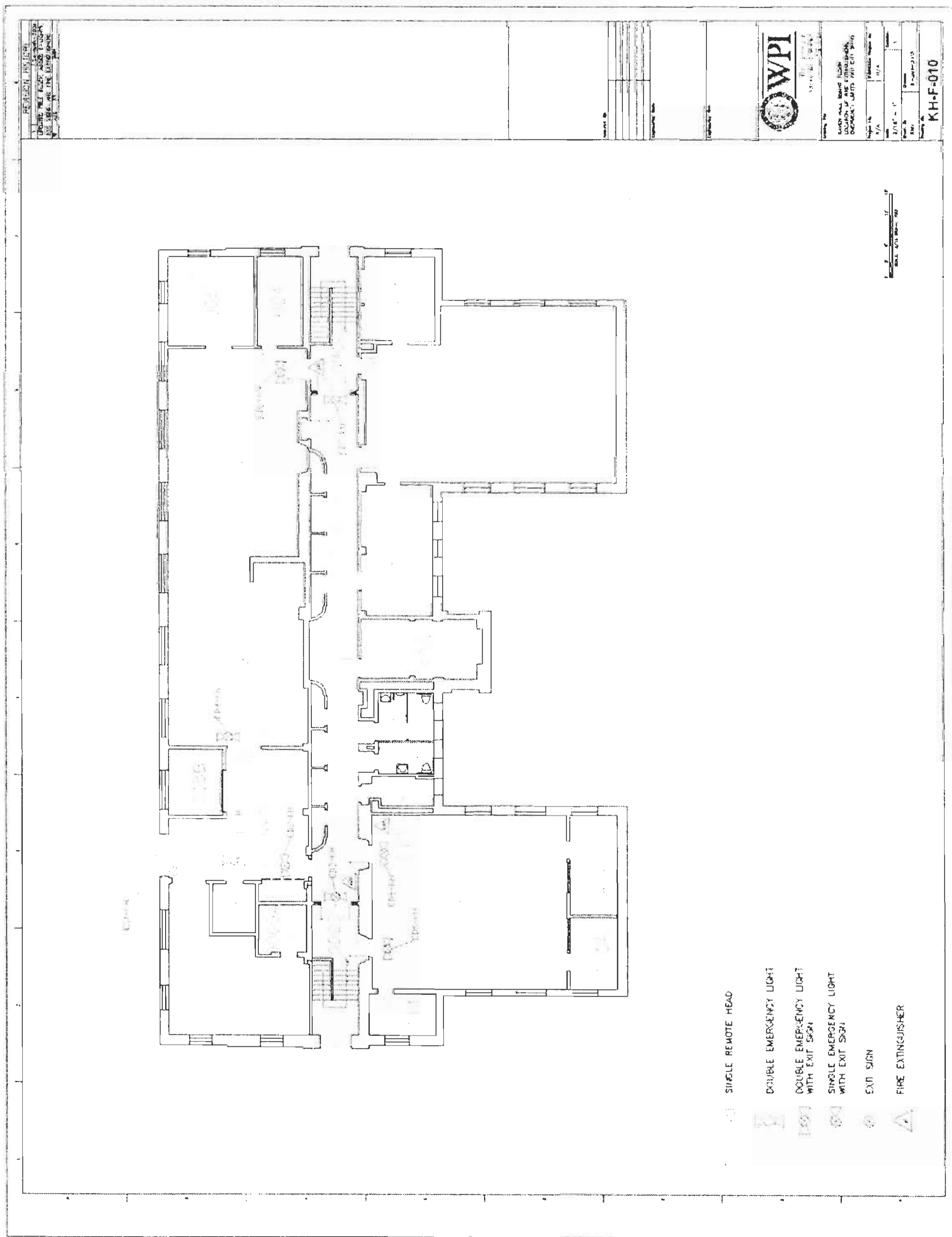



Figure 19: CAD drawing for Kaven Hall Basement

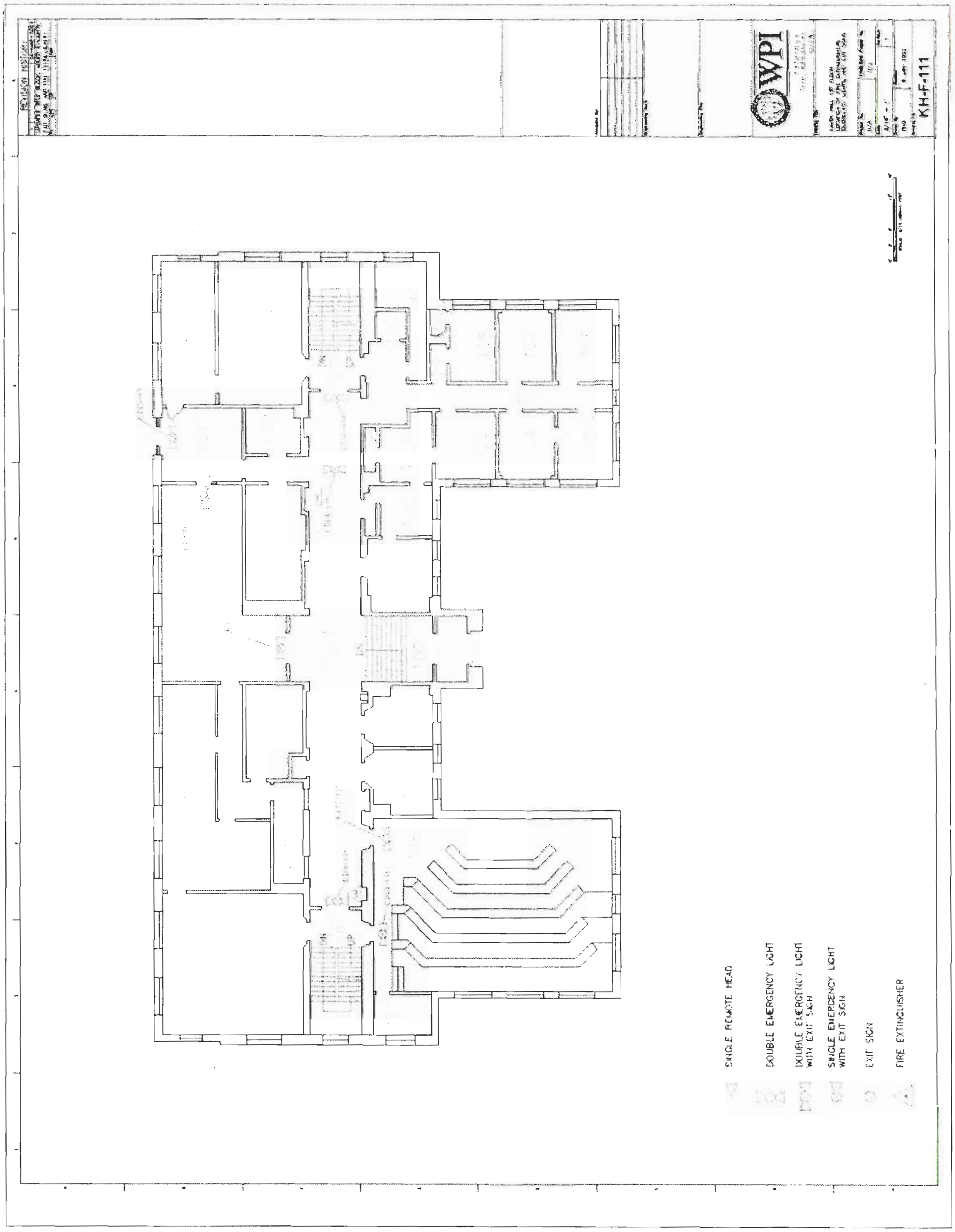



Figure 20: CAD drawing for Kaven Hall First Floor

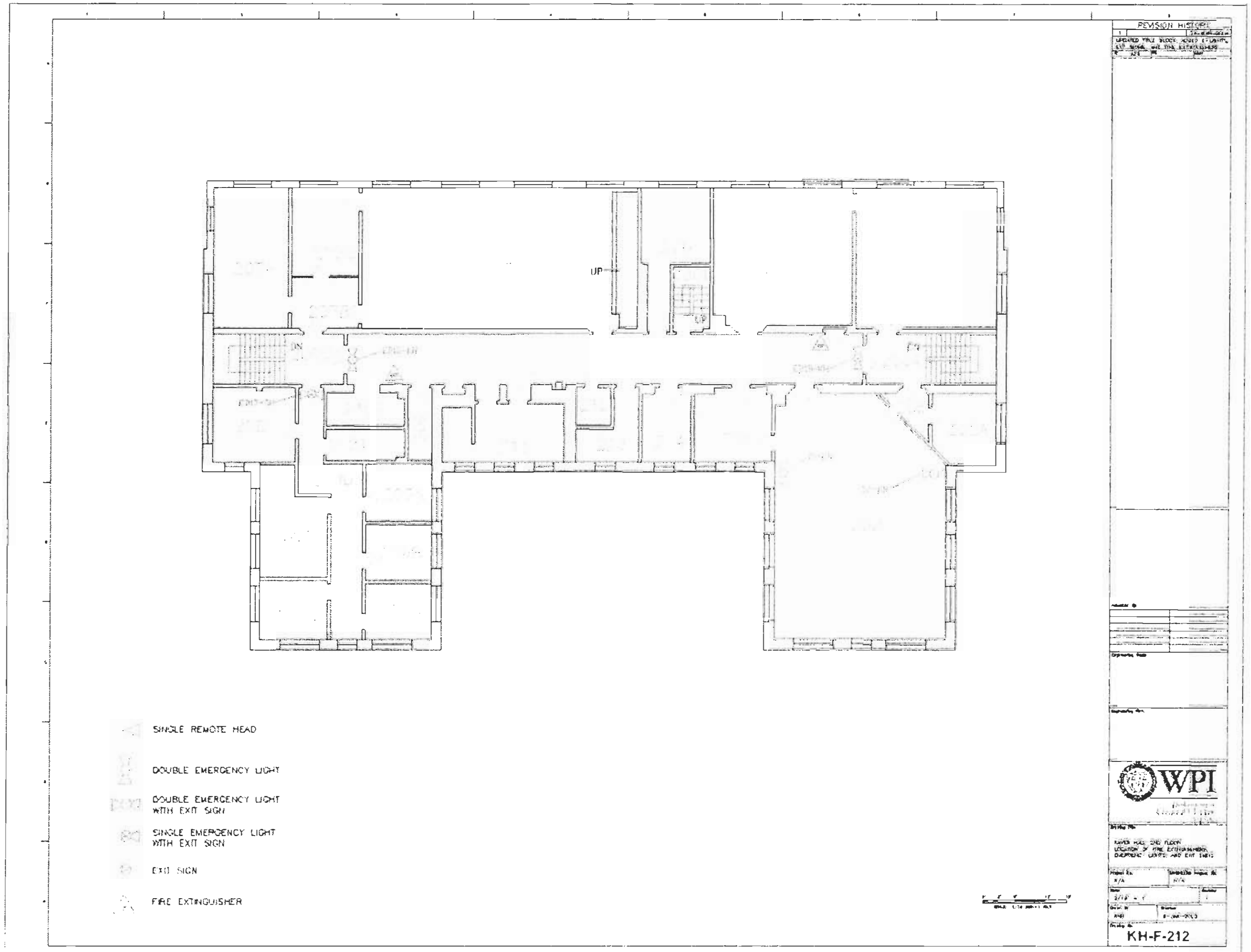



Figure 21: CAD drawing for Kaven Hall Second Floor


Figure 22: CAD drawing for Salisbury Labs Basement

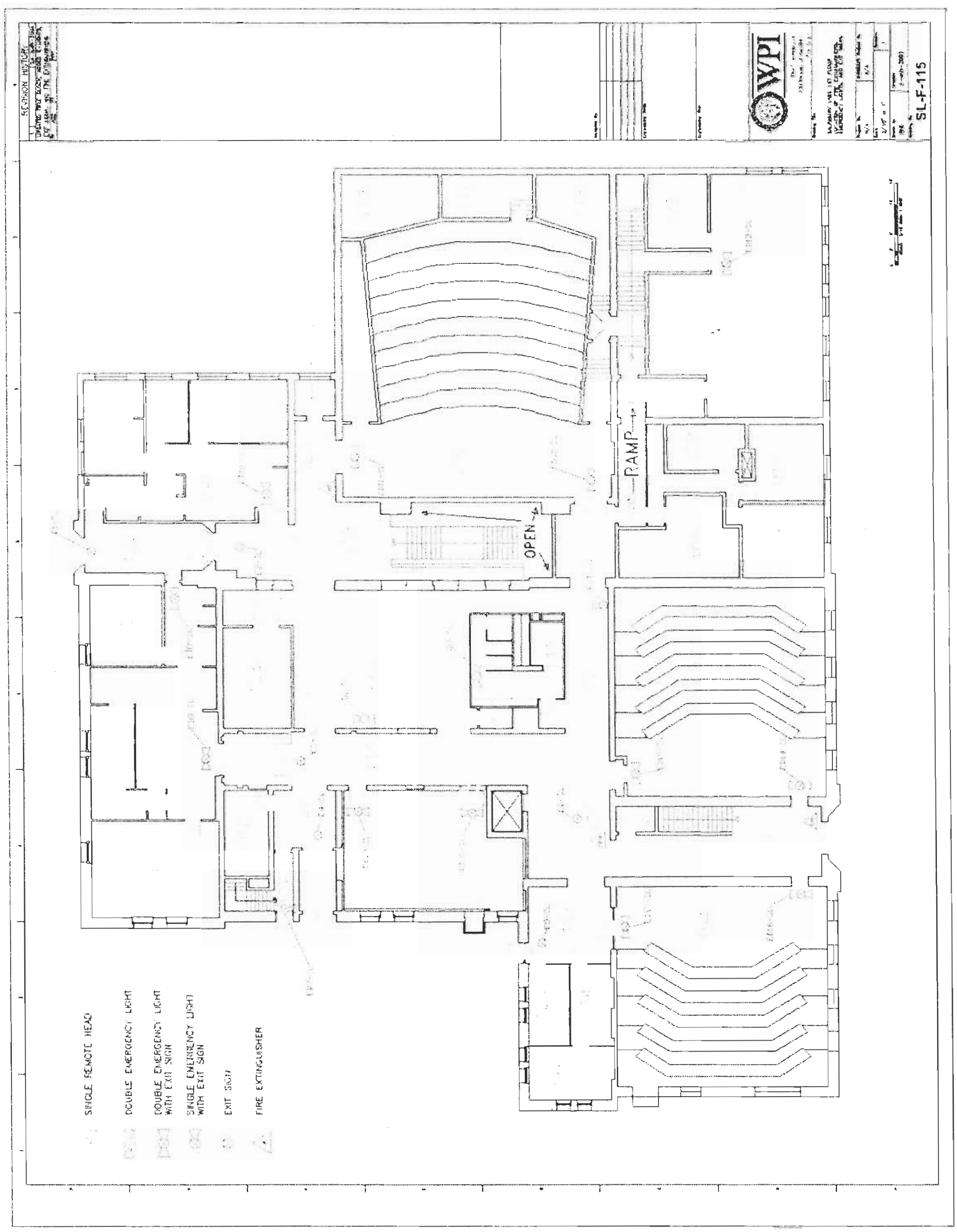



Figure 23: CAD drawing for Salisbury Labs First Floor

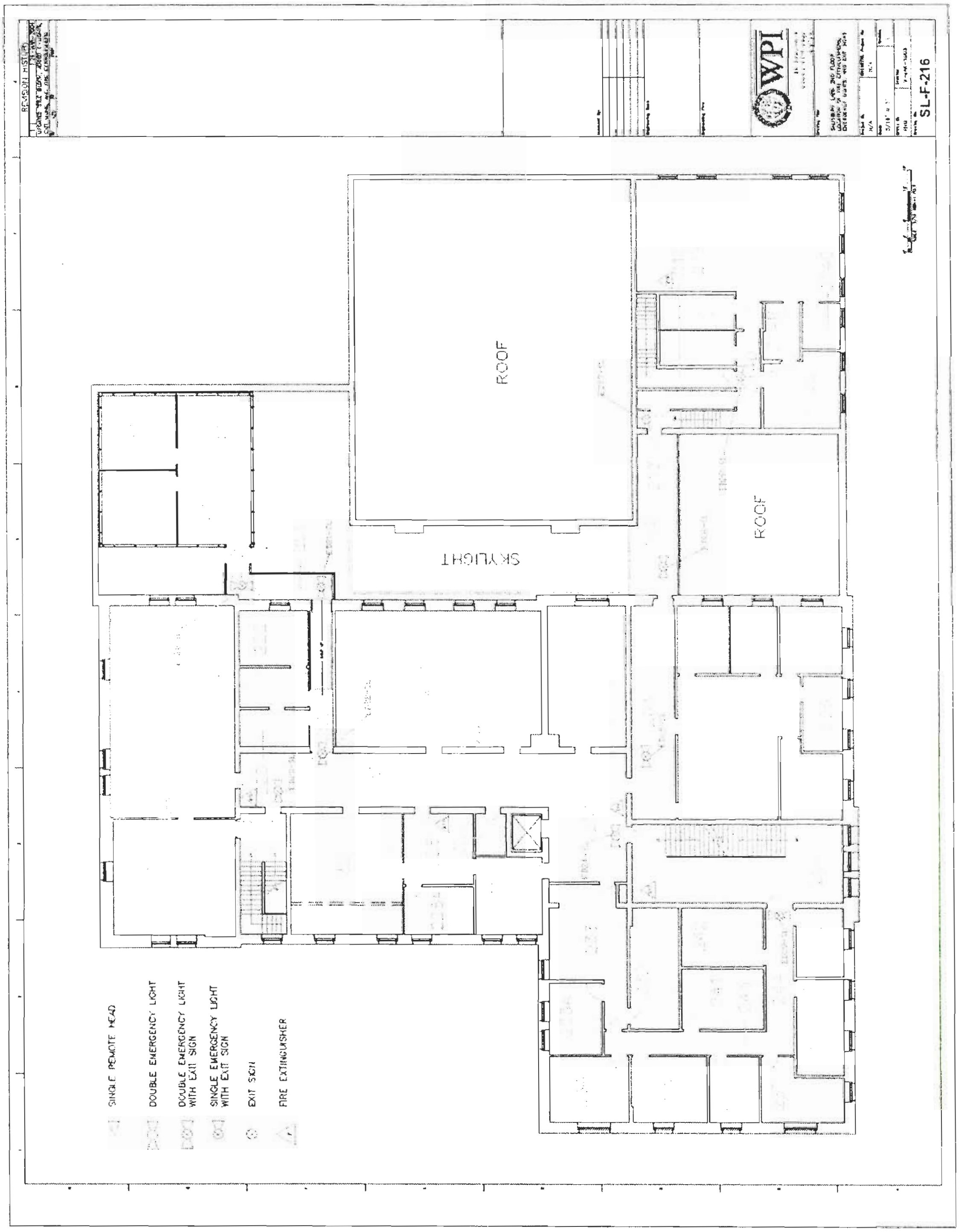



Figure 24: CAD drawing for Salisbury Labs Second Floor

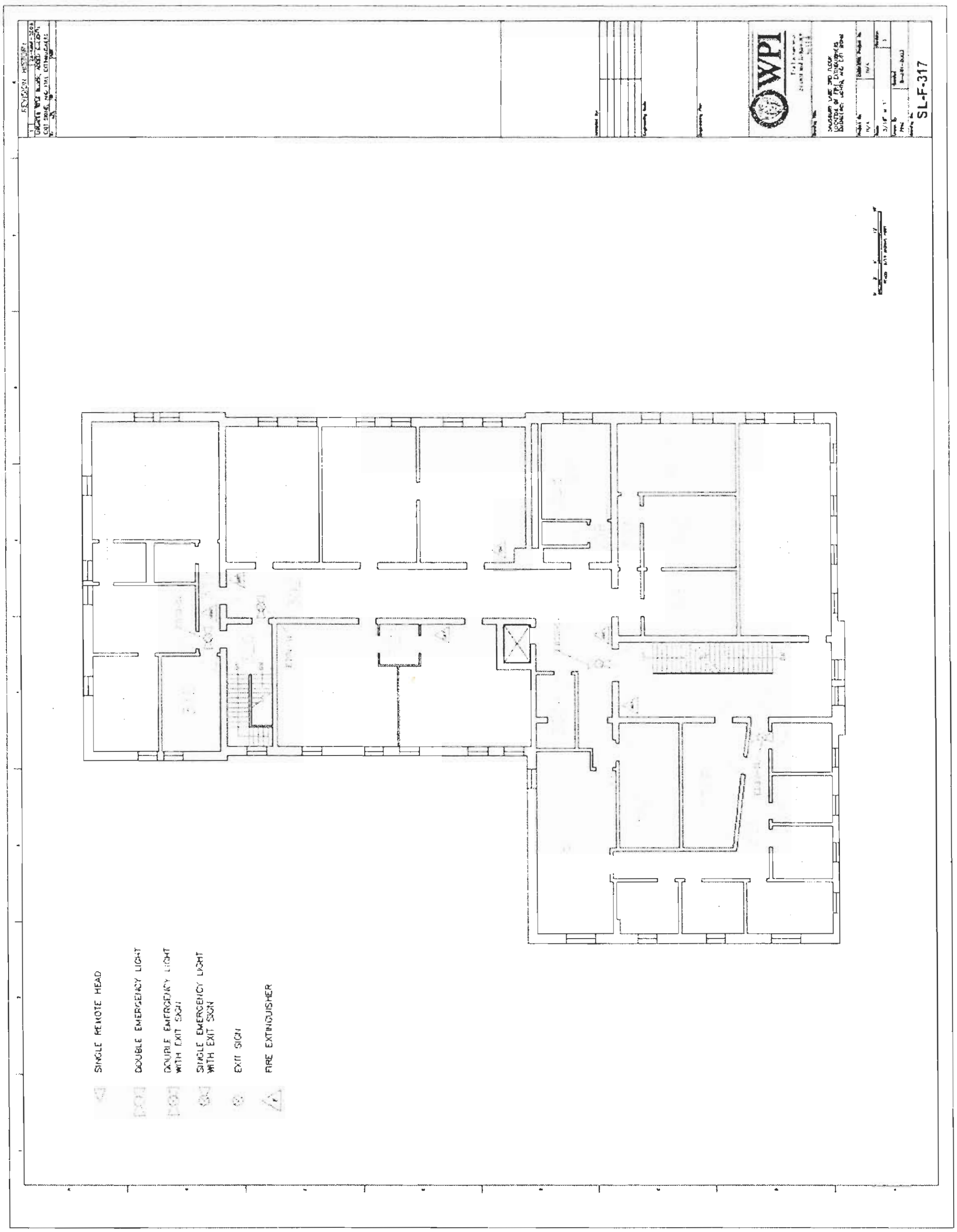



Figure 25: CAD drawing for Salisbury Labs Third Floor

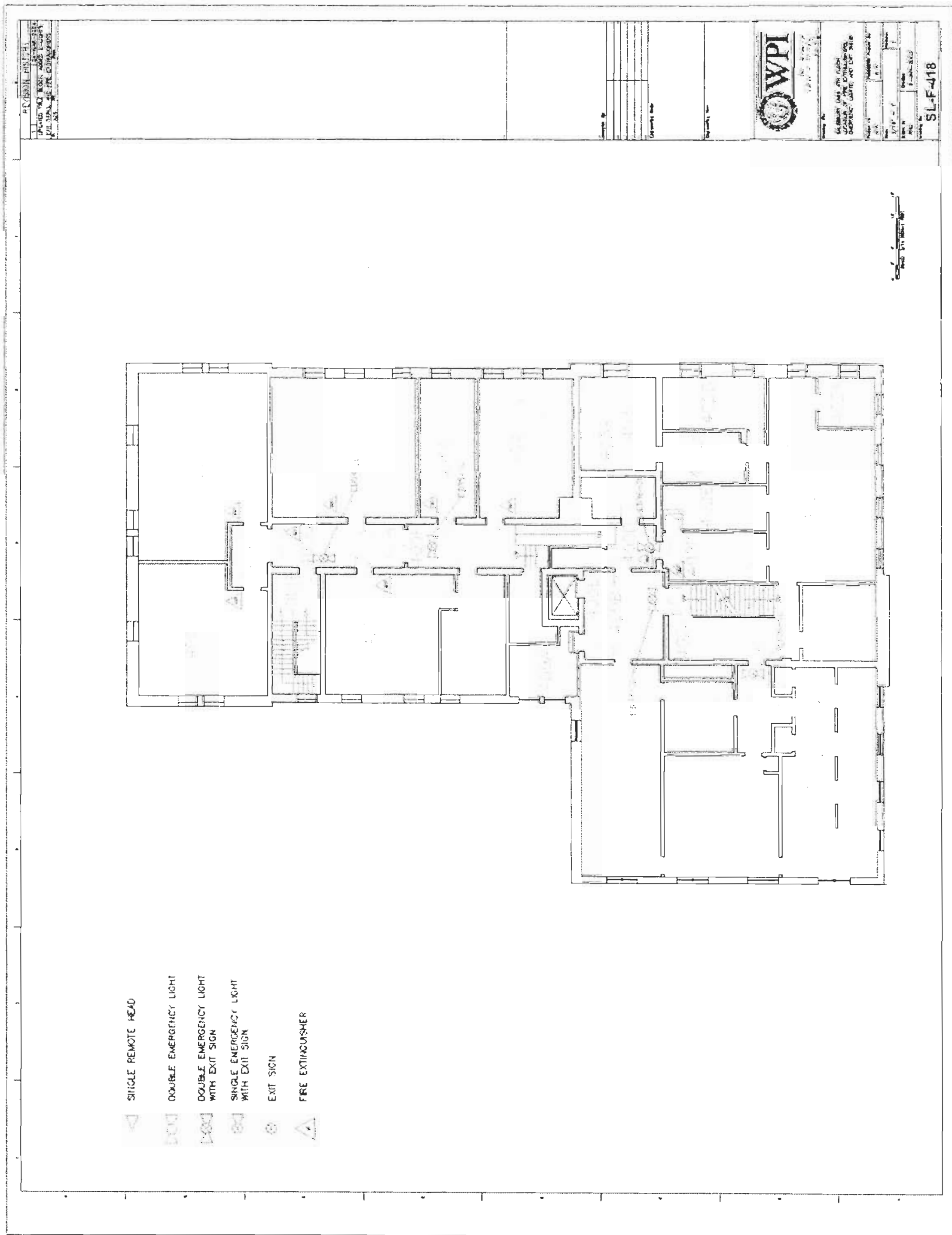



Figure 26: CAD drawing for Salisbury Labs Fourth Floor

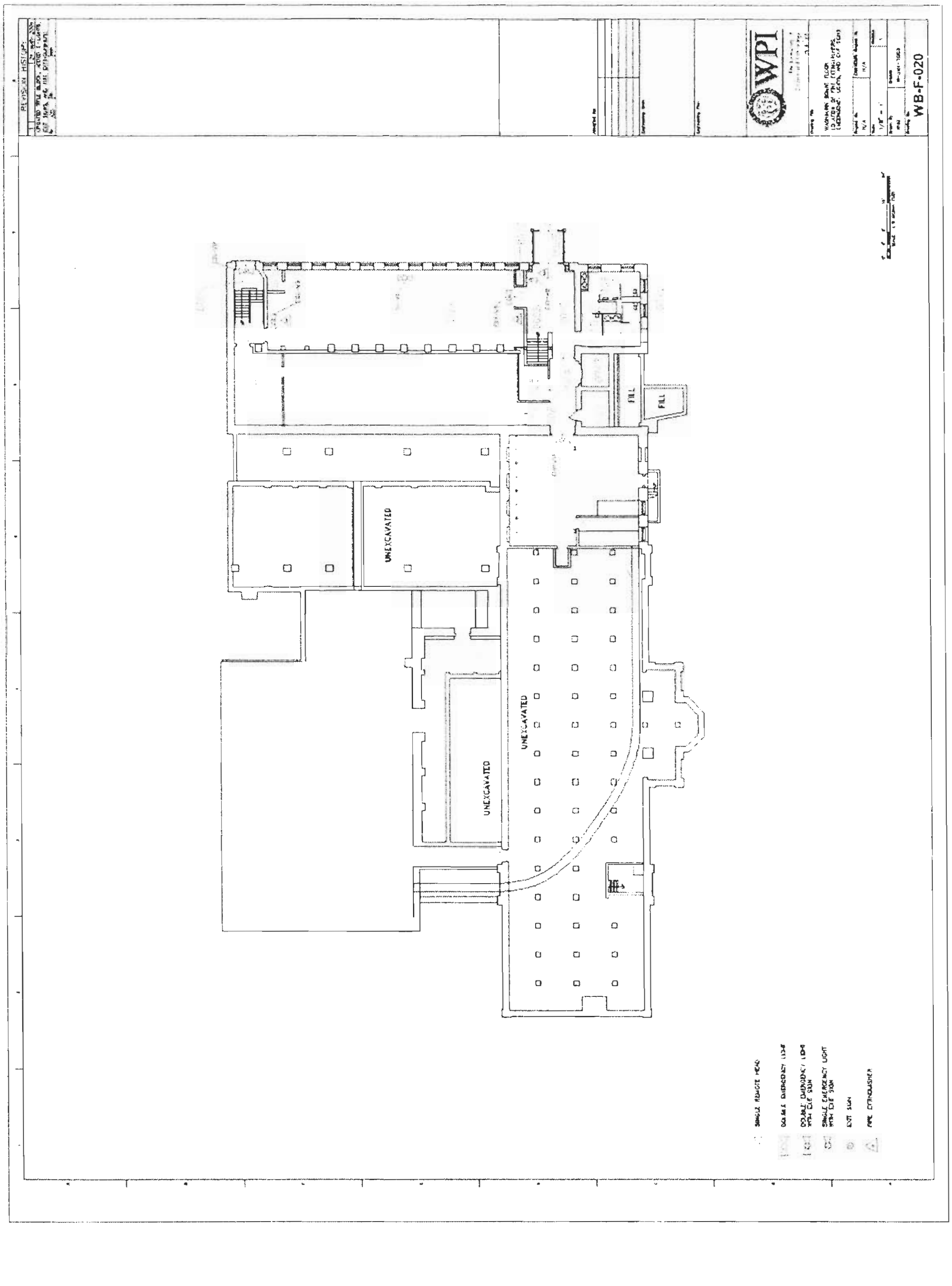



Figure 27: CAD drawing for Washburn Basement

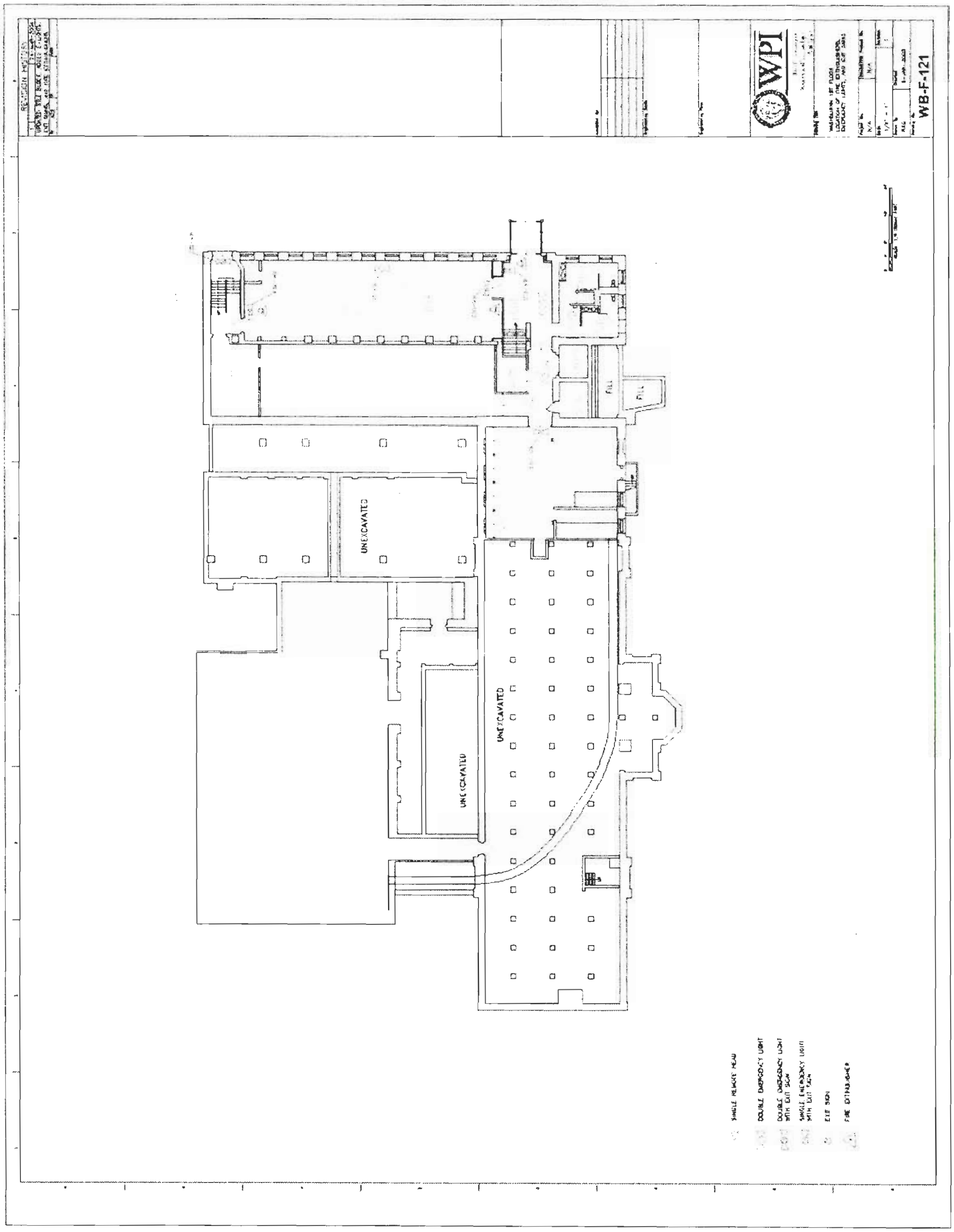



Figure 28: CAD drawing for Washburn First Floor

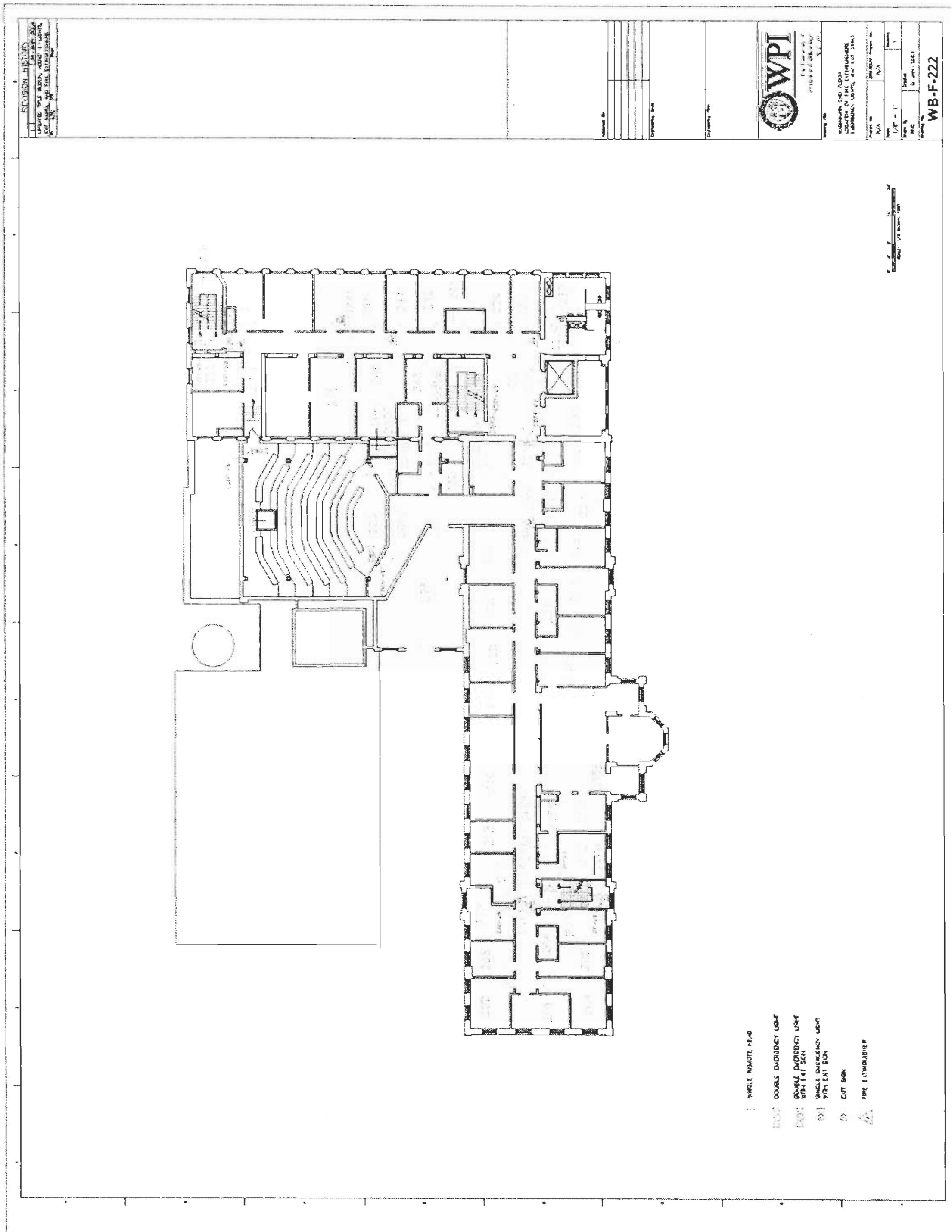



Figure 29: CAD drawing for Washburn Second Floor

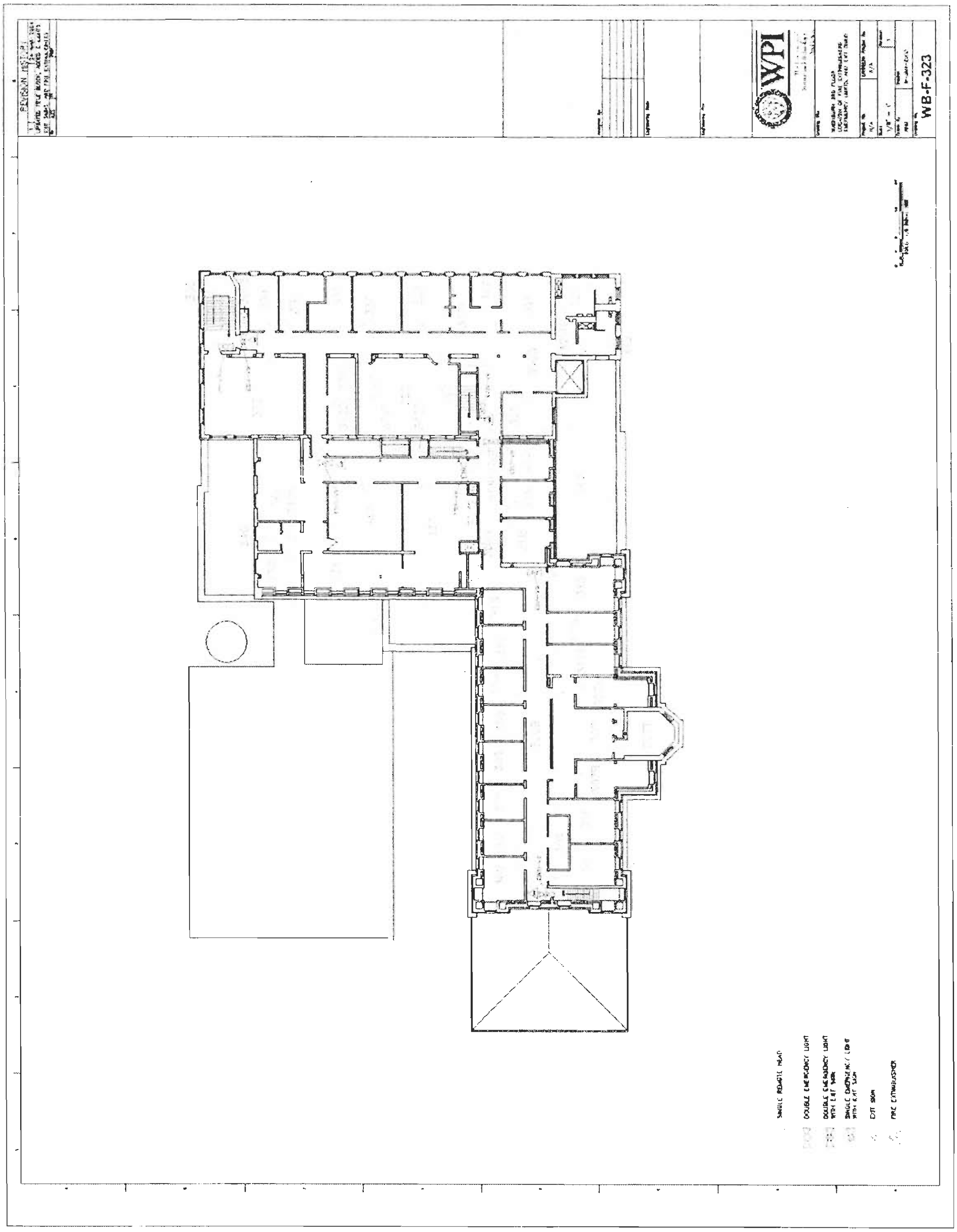



Figure 30: CAD drawing for Washburn Third Floor

# 7 Conclusions

One of the goals of this project has been to begin the process of modernizing the safety equipment records and transfer the data to a computer database. In this format, the data is much more organized and accessible, and it is expected to be easier to update and maintain the system as compared to the current system of paper documents.

Knowledge, organization, and availability of this safety device data is critical to maintaining an acceptable level of building safety. The GIS system has provided a visible demonstration of the campus building's compliance with fire-codes.

According to the head manager of plant services, the new policy of employing contractors has been effective in maintaining the fire-protection equipment.

The information system produced by the e-Safety project is a valuable resource for future IQPs that study the WPI campus.

# 8 Recommendations

The results of the data analysis have been used to formulate recommendations with the intent of improving Plant Services policies and procedures wherever possible. We have formatted the results of our project for use by WPI Plant Services to assist the department in the management and maintenance of safety equipment.

## 8.1 Maintenance Contracting

From the point of view of maintenance, it appears to be most beneficial and effective for WPI to continue to hire contractors to complete most of the maintenance work to ensuring that the fire-protection equipment is functioning correctly and is in general code compliant.

It is perceived that the maintenance contractors, including O'Connell fire protection services, appear to be highly professional and experienced. This contractual agreement appears to be satisfactory for both parties, and seems to exemplify good management practice.

However, it is important to remember that these contractors are separate organizations from WPI, and ultimately, the responsibility for the well being of the institution and its members remains with WPI and the Plant Services department. As a policy, WPI should still be considered fully accountable in the event of an accident; this is true on both an ethical and legal basis.

## 8.2 Records Maintenance

Revision of safety procedures and safety equipment documentation will require frequent maintenance to be kept up-to-date. We recommend that Plant Services continue to make these efforts to update records, because we believe that the equipment performance will be improved as a result, along with the building safety.

Our collection and organization of the WPI safety equipment data will allow future projects the opportunity to further analyze the data. Further development and maintenance of the information system will provide additional opportunities for evaluating building safety and the performance of fire-safety equipment.

It might also be useful to analyze the data to determine if there are statistical correlations between the safety precautions for a given campus building and the general fire safety in similar buildings. In other words, one could analyze historical data to ascertain which safety equipment and practices have actually provided the most protection. This type of study might indicate whether code compliance is really the best measure of fire safety and prevention; or perhaps the data could suggest that building codes are not as strictly correlated with safety as perhaps they ought to be.

## 8.3 Further Development

The system that has been developed could be expanded upon and used to analyze other pieces of safety equipment. Further development could lead to the system being used on a PDA with a wireless connection to the network. This would allow for the inspection of the equipment and the updating of records to be done simultaneously.

Development of new software such as AutoCAD 2004, allows the user to link object in the drawings to database and perform more operations to the data. Use of the developed system with new software would allow for all the analysis to be done with only one type of software.

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This site has useful information pertaining to sprinkler systems. Also location for our sprinkler pictures.

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<http://www.nsc.org>

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Spokane Regional Cross Connection Control Committee October 16, 2003 <www.src4.org>
Web site created after a group of water purveyors, city and county plumbing officials, plumbing, and backflow assembly manufacturer representatives came together to talk about issues with water control and protection. Great resource for issues about water safety and backflow prevention.

Worcester Polytechnic Institute. October 16, 2003 <http://www.wpi.edu>
Our Universities website, and gateway for many resources used throughout this project.

WPI IQP Handbook Nov. 6, 2003
<http://www.wpi.edu/Academics/Depts/IGSD/IQPHbook>
WPI's online IQP handbook, used for research of proper procedures and such for this project.

WPI project # 00E041I: "Fire Safety in Student Housing"
Prior WPI project pertaining to fire safety, a small part of our e-safety project

Webster's Dictionary. December 05, 2003
<http://www.webster.com>
Online dictionary, used for general reference purposes.