Water Systems for Interstate Safety Rest Areas: Quantity and Quality Aspects

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Interstate safety rest area facilities provide unusual water use demands. The design of water system elements can be based on the peak instantaneous, maximum hourly, and maximum daily water demand rates. The peak instantaneous demand rate establishes the required pipe sizes and the capacity of elements such as the pumps to the hydro-pneumatic tanks. The water source capacity should be equal to the maximum daily water use rate while the required storage volumes are determined by the maximum hourly use rate.

Water available from natural sources such as wells is not pure. Numerous types and concentrations of impurities present in the water supply will influence the suitability of the source. The need for bacteriologically safe water is obvious. Other constituents and characteristics, such as iron, manganese, sulfates, chlorides, nitrates, and hardness, must be considered in selection of a water source. The adequacy of the available water quantity and water quality must be considered in the early planning and development of the safety rest area facilities.

The sucessful operation and maintenance of numerous rest area facilities throughout each state will depend to a great extent on the standardization of the water systems. This design approach will be particularly adaptable to the hydraulic elements and is also applicable to many of the treatment elements of the water system.

•THE ADVENT of the Interstate Highway System and the resulting large traffic volumes from "America on wheels" led to the concept of safety rest area facilities in a number of states. Individual state requirements and desires have led to a variety of creatively designed facilities. Such rest areas are a pioneering effort to furnish a service to the traveling public. The acceptance and the current rate of use in Iowa dramatically show that the rest areas provide a service that the public uses and appreciates.

Because the author is primarily familiar with the Iowa facilities, this paper is oriented toward the Iowa safety rest area development and design program. However, the material presented on the water systems should be applicable to other design solutions for rest areas of other states.

Rest area buildings provide unusual water use and water demand rates. The major problem is that there are few specific applicable guidelines from previous installations. The magnitude of the problems involved is shown by the fact that the projected water use and demand variations of each rest area building in Iowa are equivalent to the water supply for a community of approximately 100 people. However, the water demand characteristics are different from the normal domestic situation in a community.

Thirty, forty, or more of such facilities throughout each state are development, design, operation, and maintenance problems of the first order. Yet the basic underlying problem is simply to provide water for "one of those stops." The available quantity and quality of a potential water supply are factors that must enter into the planning of the rest areas at a very early stage. In fact, the availability of water in adequate

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amounts and of proper quality can and should dictate the site selection for the rest area and the extent of facilities to be provided at the site.

WATER DEMAND

One of the first steps in selection of a suitable water supply for a rest area facility is determining the rate of demand that will be placed on the source. The vital elements of water use demand are the average daily water consumption and the peak demand rates for various time periods important in the design of facilities, such as the maximum daily, maximum hourly, and peak instantaneous demand rates. These peak demand rates need to be estimated for determination of the pipe sizes, pressure losses, storage requirements, and pumping capacity to supply sufficient water during these periods of high water use.

Some studies (1, 2, 3) have been conducted on the flow variations at the service areas along some national turnpike and toll roads. These service areas generally provide more facilities than are anticipated in the safety rest areas. The studies point out the wide variation in demands to be expected and the rapidity with which they can occur. The data, however, are not directly applicable to the safety rest areas.

The extent and type of water-consuming devices provided in a rest area building will establish the potential water use. Traffic volumes, number of parking spaces, and other factors will determine how fully the water-using potential will be realized.

Water demands and other aspects of the water systems in the Iowa rest area buildings will be referred to for comparative purposes throughout this paper. The rest areas are usually in pairs, nearly opposite each other. Currrently, each building has a separate water system. Approximately half of each 30- by 34-ft building is devoted to rest room facilities. In total, each building has eight toilet fixtures, (water closets or urinals), four lavatories, three drinking fountains, and one service sink as the primary water-consuming devices. Two outside hose connections are provided for watering lawns.

Various portions of a water system will be designed for the water demand during particular time periods. For example, the individual pipes to each fixture must be sized to meet the maximum momentary water-use rate for that fixture at adequate pressures. The main water supply piping, however, does not need to meet the sum of all fixtures simultaneously because all fixtures will not be used at the same instant.

The peak demand flows on which to base the design of the water system should reflect the expected pattern of operation and meet the needs of the particular type of installation. Any numbers must be tempered with experienced judgment.

Peak Instantaneous Water Demand Rate

If all fixtures installed in one Iowa rest area building were used simultaneously, the total water demand would be 590 gpm (gallons per minute). Obviously, and fortunately, this will never happen. The demand imposed on building water supply systems cannot be predicted exactly. Although some fixtures, such as hose bibs, will impose a continuous water use, it must be recognized that the plumbing fixtures are used intermittently and the probability of simultaneous use of such fixtures cannot be definitely established.

A standard method (4) for estimating the peak instantaneous demand on a building water supply system has evolved that has proved to be satisfactory for many combinations of building fixtures, occupancy, and use. The studies of plumbing installations using statistical methods by Hunter (4) were a landmark in engineering design. The results of this work have been incorporated into the National Plumbing Code (5).

Numerous field tests as well as the test of time have proved that this standard method is widely applicable. In the standard method, fixtures that use water intermittently under different service conditions are assigned demand load values in terms of fixture units. One fixture unit is equivalent to a flow rate of 1 cu ft per min or 7.5 gpm. Applicable values for different fixtures are given in Table 1 (5, 6). The relationship between the total fixture units and the peak instantaneous water demand rate is shown in Figure 1.

Applying the fixture unit values in Table 1 and the relationship in Figure 1 to the rest area buildings in Iowa (79 fixture units) yields an estimated peak instantaneous water demand rate of slightly over 60 gpm. This is somewhat less than the 590 gpm based on the simultaneous use of all the fixtures. Any continuous water demand such as a connection for lawn watering should be calculated separately and added to the peak instantaneous demand. Any water system using pumping as the basic supply device should have a pumping rate nearly equal to this peak instantaneous demand rate. This situation fits the hydro-pneumatic tank and the direct booster pumping systems.

TABLE 1

WATER DEMAND LOAD OF FIXTURES, PUBLIC OCCUPANCY

Fixture	Supply Control	Fixture Units[a]
Water closet	Flush valve	10
Water closet	Flush tank	5
Urinal	Flush valve	5
Urinal	Flush tank	3
Lavatory	Faucets	2
Service sink	Faucets	3
Drinking fountain	Valve	1

[a]The given weights are for total demand. For fixtures with both hot and cold water supplies, the weights for maximum separate demands may be taken as three-fourths of the listed demand for supply.

The fixture unit values of Table 1 and the relationship to peak instantaneous water demand rate in Figure 1 show that the flush tank type of plumbing system could reduce this demand rate by about half. However, the flush tank system is more susceptible to vandalism, uses more water per flush even though at a lower peak rate, and the rate of proper fixture use is controlled by the time for refilling the flush tank. For these reasons, the flush valve system is used almost exclusively for public facilities such as the rest area buildings.

This particular peak instantaneous rate for a water system is based on considerable past operational experience, and as such is estimated on a sound basis.

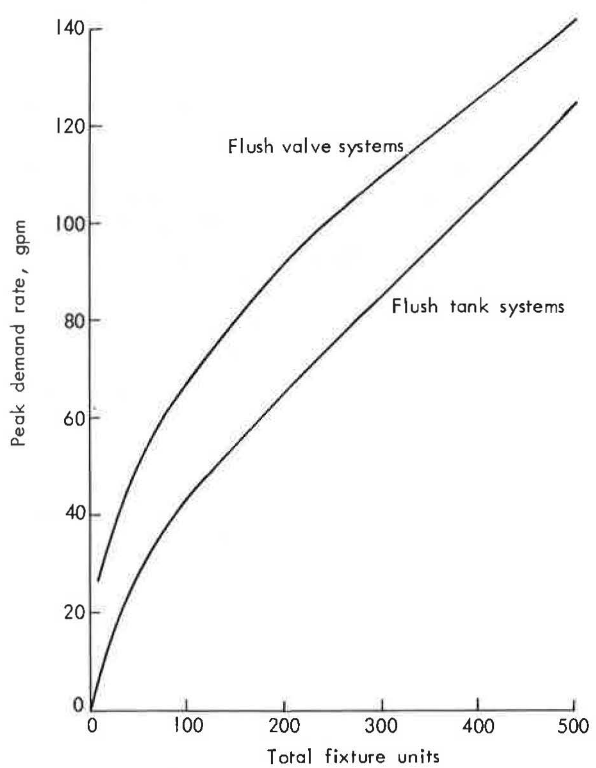

Figure 1. Demand load estimate curves.

Maximum Hourly Water Use Rate

Unfortunately, the water use rates for other time periods are not so well determined. There is a real paucity of specific data applicable to the rest area buildings.

An estimate of the ratios between the peak instantaneous and the maximum hourly water use rates can be obtained from criteria such as the "Federal Housing Authority Guide for Engineers—Rural Community Water Systems" and other criteria and studies (1, 2, 3, 7, 8, 9). It must be pointed out that none of these criteria or studies provide the desired ratio directly, peak instantaneous demand rate to maximum hourly water use rate. But by considering the ratio of average daily use to maximum daily use and the maximum hourly use to maximum daily use and in turn the estimated peak instantaneous water demand, an expected ratio of two can be reached. When this ratio is applied to the situation in the Iowa rest area buildings, the estimated maximum hourly water

use rate would be 30 gpm. It is quite apparent that this number leaves considerable room for doubt. The extension of some of the studies is difficult, but as was pointed out before, engineering judgment and common sense are required.

In an attempt to provide a more rational design basis, several studies were conducted by Iowa State Highway Commission personnel, including hourly water use readings as well as traffic counts on the main traffic stream and on the traffic into the safety rest areas. These studies confirm the validity of the rate given. By actual count, 2067 people per 16-hour day enter a single safety rest area site for an average of 130 people per hour. A great many counts at these rest area sites have established that the peak hour traffic in flow volume is about three times the average or 390 people per hour entering the site.

These studies have further shown that about 70 percent of the people use the rest room facilities. This means that during the maximum hour, about 295 people are using the rest room facilities. Estimating a water use of 5 gal (3 to 5 gal per water closet or urinal, $^3/_4$ to $1^1/_2$ gal per lavatory use), this yields a maximum hourly water use rate of about 25 gpm, which is quite close to the 30 gpm previously determined. It is interesting to note that the recommended water use criteria (8, 10) for service stations of 10 gal per vehicle will yield approximately the same water demand rate, allowing 3 people per vehicle, as previously determined.

Maximum Daily Water Use Rate

Similar considerations yield a ratio of the maximum hourly to the maximum daily water demand rate equal to approximately two. This ratio can be estimated with a fair degree of accuracy from a number of sources (7, 8, 9). Applied to the Iowa rest area buildings, this ratio would yield a maximum daily water use rate of 15 gpm.

This particular water use figure will be highly dependent on other factors, notably parking spaces provided and traffic volumes. The potential for this water use can be present, but the actual use limited. Several years of operating experience are going to be needed to more fully define this situation.

Daytime Water Use Rates

In the normal design of a water system for domestic services, the high hourly water use rates will occur in the early morning, at noon, and in the evening, roughly corresponding to meal times. Safety rest areas present a quite different pattern, as shown in Figure 2. The data shown in Figure 2 are the average and the maximum hourly water uses determined at twelve different rest area buildings in the studies by Iowa State Highway Commission personnel. As can be seen, the demand rate for a considerable length of time during the middle of the day is above the average for that day. This means that an appreciable draw will be placed on the water supply facilities for a number of consecutive hours in the middle of the day.

Also, more than 80 percent of the daily water use will occur in the 16-hour period from 6:00 a. m. to 10:00 p. m. It is for this reason that the average daily flow is such a poor design value to consider.

Summary of Water Demands

Two particular aspects of the water use variations dictate that the design basis for Interstate safety rest areas should be the maximum daily use rate with its attendent maximum hourly and peak instantaneous demand rates. First, the peak instantaneous water demand could occur on any day of the year, even the lowest water use day. In fact, a single busload of people could exert this demand rate several times during a 10- or 15-minute period. Second, the maximum daily water use rate or just slightly less will probably occur for extended periods of days during the summer vaction travel period in a pattern similar to that shown in Figure 2. The maximum daily water use rate establishes the required capacity of the water supply source. This is an important design parameter because it is anticipated that this demand rate or slightly less will be sustained for several days at a time during the high summer use period.

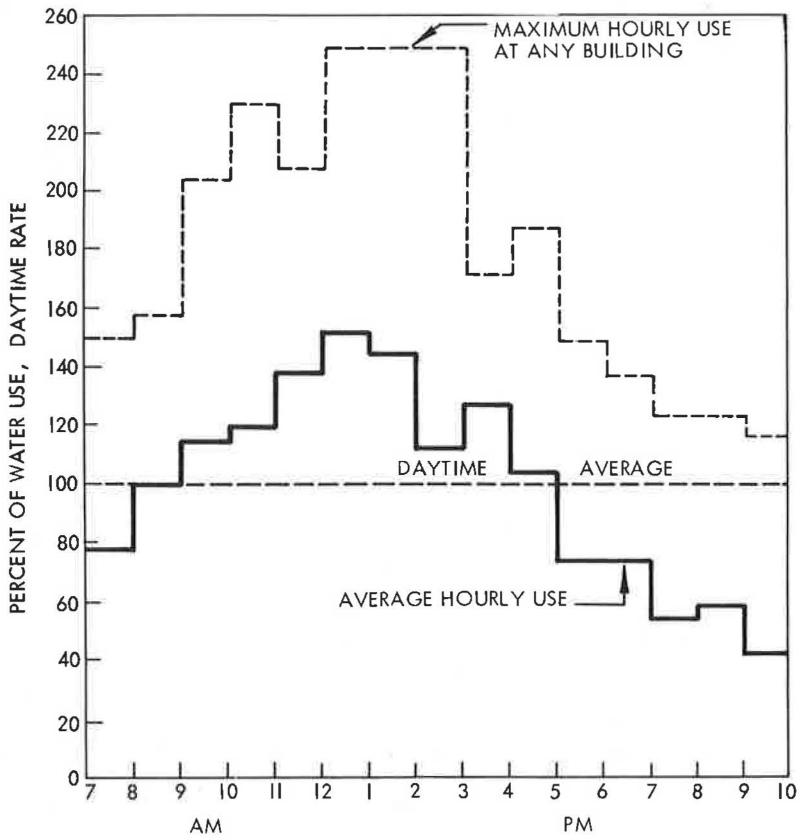

Figure 2. Interstate rest area water use variation (12 buildings).

The individual fixture water use rates determine the pipe sizes to the particular fixture. The combination of fixture units through the development of the peak instantaneous demand rate will establish the main supply pipe sizes all in accordance with standard plumbing design.

As previously mentioned, the peak instantaneous water demand also will establish the required capacity of the supply pump for a hydro-pneumatic tank or a booster pump system. The hydro-pneumatic tank is the most common installation of the safety rest area buildings.

The maximum hourly water demand rate and the rates during the daytime demand period are used in the design of storage volumes or pump cycle times, as will be discussed later.

WATER QUALITY

The quality of available water supply sources is an extremely important consideration because it will affect the design of several other elements of the water system. This parameter of quality should be considered very early in the planning stage. The quality of potential water supply sources should be considered strongly in the safety rest area site selection. People expect drinking water to be biologically safe, attractive to the senses, soft, and nonstaining as well as noncorrosive or non-scale-forming. The public will demand this type of water and will get it.

The basic criteria for water quality evaluation are the "Drinking Water Standards" of the U. S. Public Health Service (11). These standards are the criteria used by most government agencies and are obligatory for water supplies furnishing water to interstate

carriers. If not legally bound, the individual state highway agencies should certainly feel morally obligated to meet these minimum standards for drinking water along Interstate rest areas.

Water quality is determined by the bacteriological, physical, and chemical characteristics of the water. The first and most important criterion to be met is the provision of a bacteriologically safe drinking water. Well water supplies are generally quite safe, and because wells are the most common water source for the Interstate safety rest areas, the bacteriological quality is usually no problem. However, it is not axiomatic that all wells are bacteriologically safe, and well supplies should be tested, not just at the time of completion and start-up, but on a regular periodic basis. A monthly sample is the minimum that should be considered. A proper sampling program will provide an adequate safeguard for this aspect of drinking water quality.

The physical quality of a water supply is related to the temperature, color, turbidity (clarity), taste, and odor. The color and turbidity limitations of the "Drinking Water Standards" (11) are such that the general public will reject use of a water long before these particular limits are reached. The excellent quality water supplied daily by the municipal waterworks industry has set pseudo-standards of quality that the public will also demand from the safety rest areas.

The taste and odor aspect of a water is difficult to evaluate in a quantitative manner, because each person has a different sensitivity to this quality. A particular source of problems is the hydrogen sulphide odor (rotten eggs) prevalent in many well supplies. This is easily removed in water treatment, however.

The water temperature plays an important role in the taste problem. Many tastes will not be noticeable when the water is cold. For this reason it is strongly urged that water coolers be used when the temperature of the water source is high. A single bad taste of water can ruin an individual's good will toward the rest area facilities and vista.

The third area of the standards to be considered is the limitation on certain chemical constituents. The limitations of permissible concentrations of toxic materials such as arsenic, boron, and selenium must be met. Other far more commonly found chemical constituents, the allowable concentration, and the effect of these constituents are considered in the following.

Iron and Manganese

The presence of iron and manganese can cause stains on plumbing fixtures and coatings in pipes and hot water heaters, as well as some taste problems. In addition, red or, more commonly, yellowish-red colored water will occur when the water is exposed to the atmosphere. Almost all well waters in Iowa and in many other parts of the country contain these minerals in excess of the limits of 0.3 mg/l.

Calcium and Magnesium

Hard water is caused by calcium and magnesium salts; although there is no limit on hardness per se, the magnesium level should be below 125 mg/l. The calcium and magnesium salts in hard water can cause deposits in pipes, reducing their capacity, and in hot water heaters particularly.

The possible extent of such coatings was well demonstrated in an Iowa rest area building that had an extremely hard water supply. In that instance, a 1½-in. drain pipe connected to a urinal was coated to a point where the inside diameter of the pipe was about the size of a pencil. This had occurred within about a year of operation. The possible problems in 15 or 20 years of operation are quite apparent under these circumstances. The need to soften the hard water is obvious in this instance in order to prolong the life of the piping and fixtures.

Nitrates

The presence of nitrates near the 45 mg/l level can cause nitrate-cyanosis in infants (blue babies) if the water is used in formula. Most uncontaminated water supplies are considerably below this limit, but it is an important item to consider in evaluating water quality for rest areas.

Chlorides

Above the level of 250 mg/l, particularly in conjunction with high sodium concentrations, drinking waters may have a salty taste to some people. Certain people may also experience a degree of laxative effect from this type of water.

Sulfates

Drinking waters with a sulfate concentration above 250 mg/l will produce a laxative effect on most people, particularly if the sulfate is combined with a high magnesium concentration (epsom salts). The presence of high total dissolved mineral content also promotes this laxative effect.

Many communities in the United States have water supplies that exceed these sulfate concentration limits and the inhabitants become acclimated to the water. The acclimatizing process can be discomforting under normal domestic conditions. The traveling public does not have the time to become acclimated and the laxative effect on a traveling family could be completely disastrous. Rest areas could not be spaced closely enough.

WATER SYSTEMS

Sources

There are three primary sources of water for the Interstate safety rest areas. The first and probably the most desirable, if close enough, is a municipal supply. The capital and maintanance costs involved with water supply and treatment for a rest area building could pay for appreciable pipe line construction from nearby communities. In any case, this is a first consideration when investigating water supply sources.

The second and by far the most commonly used water supply source is wells. There are relatively few areas in the United States where a well supply cannot be developed. The water quality from well supplies, however, can sometimes be less than desirable.

The third possible source is surface water such as a river or lake. Because of exposure to the atmosphere and the elements, such water supplies can be extremely variable in quality. They are always subject to pollution, and treatment will always be needed. Chlorination is the very minimum treatment possible. As such, a surface supply will present many more operational and maintenance problems than a well supply for small installations. Surface water sources should be avoided if at all possible.

Water Treatment

The wide variation in water quality that can be expected across the country means that a single series of treatment operations will not be satisfactory for every water supply. The quantity of water required will also play an important role in the treatment process selection. In fact, the relatively small size of the rest area water systems creates problems in this respect. The water systems are larger than the single-family size but considerably smaller than most municipal systems, both sizes of which have treatment processes and equipment commonly available. Because so many of the water sources are wells, the following comments are intended solely for a well supply source.

Iron and Manganese—With relatively few exceptions, iron and manganese removal for well water supplies will be needed. No one treatment method is satisfactory for all iron- and manganese-bearing waters. The soft, low pH waters of the southern and southeastern states will require entirely different treatment from the hard, neutral, or alkaline waters common in the midwestern and western states. The basic process recommended for the Iowa water supplies was pressure aeration followed by pressure sand filtration. Provision for pH adjustment or chlorination in a few well supplies was also recommended. Even then, there were some well supplies in the state with excessive carbon dioxide that were not suitable for this basic and simple process.

The iron and manganese problem occur most commonly when there is a need for relatively large storage of the water due to hydraulic capacity limitations. When the

iron-bearing water is exposed to the air, the iron or manganese is oxidized, which leads to the yellow color and turbidity of the water. This will be a problem in Iowa, where large 10,000-gal storage tanks are being installed with no provision for iron and manganese removal.

Waters that have iron and manganese only slightly above the limits can often be treated with phosphate compounds. These compounds can prevent the oxidation of the iron or manganese and thus prevent the color and stain problem.

Softening—As with iron and manganese removal, the need for softening will vary. The tendency toward corrosion or scale formation is directly related to the hardness of the water through the calcium content. The treatment process, then, becomes quite important in adjusting the characteristic of the water to a non-scale-forming or non-corrosive water.

There are situations where the need to soften is quite apparent, as in the case previously mentioned. Most water supplies will not be this hard, however. Although this limit is somewhat arbitrary, when water supplies are harder than 200 mg/l of $CaCO_3$, softening should be seriously considered.

Common commercial cation exchange units can be used to soften the water supplies in most cases. These units are cation exchangers on the sodium cycle (zeolite softening). The reduced maintenance costs and increased life of the facility fixtures and plumbing can pay for the extra cost of water softening many times over, particularly as the hardness of the water increases.

A subtle but important benefit which can often be obtained in the water softening process is that the cation exchange resins will also remove iron and manganese. In fact, these are two elements which tend to foul the resins if too much iron and manganese removal is attempted. However, for those waters where the iron and manganese level is only slightly above the recommended limits, a softening unit can provide the needed treatment in one step.

Sulfate Removal—The following comments about sulfate removal are also generally applicable to chloride and nitrate removal, all of which are extremely difficult.

One available method for sulfate removal is complete demineralization of the water, together with blending of a portion of the untreated water to provide some taste in the drinking water because demineralized water is not palatable. The only water use requiring such treatment would be the supply to the drinking water fountains, and thus the quantities involved are small. The demineralization process is expensive and requires periodic regeneration of resin beds with strong acids and strong caustics. It is not a simple process to consider and should be avoided if at all possible.

A second possibility for sulfate removal is treatment by reverse osmosis. This is one of the methods being proposed and under study for desalting sea water. Again, both the first cost and the operational costs are high. This process is currently in use and under study by the Iowa State Highway Commission; it is hoped that some results will be available in the near future.

In this writer's opinion, if the magnesium removal is provided by softening the rest area water supplies, the problem will be greatly alleviated even if the sulfate concentration is somewhat above that outlined in the "Drinking Water Standards" (11).

Provisions for Water Pressure

There are three general methods of providing the required water pressure for operation of the rest area facilities. The first to consider would be elevated water storage, either tank or standpipe type. This system has the advantage of easily providing water for the variable and peak-type water demands that exist in the rest area facilities. The primary disadvantage is the initial cost where relatively flat terrain is encountered. Freezing problems may also occur during the low demand periods in the winter months. The freezing problems can be handled by judicious operating procedures. For example, only a portion of the storage volume available could be used during low demand periods to insure adequate turnover of the stored water to prevent freezing. The cost problem in flat terrain still remains. Where the terrain is favorable, i. e., a hill 40 to 50 ft or more above the rest area buildings, this type of

pressure supply is recommended over all others, particularly when the rest area buildings are in a pair and can be combined into one water system.

There are a number of design possibilities for elevated storage, such as architectural treatment for aesthetics and incorporation into uses such as lookout towers. This is an area where some very original and creative designing is possible. Whenever possible, the provision of elevated storage should be considered as the first alternative to provide water pressure. In fact, this could and should be incorporated into the planning process of site selection.

The second possibility is booster pumps used in parallel to provide the water pressure required with only nominal storage for pump suction purposes. This type of pressure system is well-suited to a fairly uniform water demand with only occasional periods of high usage. This is not the type of water demand experienced at the rest areas, and thus this type of direct booster pumping system is not applicable.

The third possibility is a hydro-pneumatic tank system, which is the system presently used in most rest area facilities. Although not as well-suited to widely varying demand rates as is elevated storage, a properly designed hydro-pneumatic system will function very satisfactorily. A common misconception about the hydro-pneumatic tank is that it provides water storage. It does not. The primary purpose of a hydro-pneumatic tank is to provide water pressure between certain limits, commonly 40 to 60 pounds per square inch (psi). The ability of a hydro-pneumatic system to meet the peak water demands is dependent solely on the capacity of the pump supplying the hydro-pneumatic tank. This pump should be equal in capacity to the peak instantaneous demand rate in order to insure proper use of all the fixtures.

The total tank volume required is determined by the number of pump cycles that can be tolerated during the maximum hourly water use period. The maximum recommended number of pump cycles per hour varies from two to ten depending on the guidelines used and on the degree of reliability required. Ten cycles per hour is the most common recommendation for the normal 1800 rpm pump motor. The number of cycles per hour is reduced as the horsepower and/or the speed of the electric motor increases.

As shown in Figure 2, the water demand rate for the period from about 10:00 a. m. to 3:00 p. m. is sustained only slightly below the maximum hourly demand rate. The commonly used submersible well pump motors generally operate at 3600 rpm. In view of this it is recommended that, when a well pump supplies a hydro-pneumatic tank directly, the number of pump cycles per hour be limited to five. However, when booster pumps (which operate at 1800 rpm) supply the hydro-pneumatic tank, the number of pump cycles per hour can be increased to ten.

On this basis, the pump supplying the hydro-pneumatic tank for the Iowa rest area buildings should be capable of meeting the peak instantaneous demand of 60 gpm previously determined. Likewise, for a maximum hourly demand rate of 30 gpm previously determined, the total volume of the hydro-pneumatic tank should be 360 gal for an 1800-rpm booster pump. The tank would need to be 720 gal if a 3600-rpm well pump is used. Both of these volumes are based on using the 40- to 60-psi operating range.

The maximum possible volume of the hydro-pneumatic tank used per cycle when operating at the 40- to 60-psi range is 27 percent, if the tank is 27 percent full at 60 psi and empty at 40 psi. This is not particularly satisfactory in practice, and generally the hydro-pneumatic tank would be operated so that the tank is 30 percent full of water at 60 psi and 5 percent full at 40 psi, thus allowing some safety factor.

In order for the hydro-pneumatic system to function properly, controls should be provided to add or vent air as required and thus maintain the proper air-water ratio in the tank.

Operation and Maintenance

One of the most important features that must be designed into rest area water systems is simplicity of operation. It is important that all of the equipment and treatment processes selected be simple, automatic, and essentially free of the "human element." The desired water system design and equipment should produce excellent

quality water satisfactory to all people, even when the system and equipment is improperly operated and not maintained. This is somewhat of a Herculean task and not a design problem for the novice. Qualified expert design advice is needed. The problems of the small water system are practically as complex as the much larger municipal and industrial water systems.

The operation and maintenance of these water supply systems at scattered locations throughout each state will be difficult. Just the problem of spare parts for 30 or 40 well pumps, each slightly different, is unpleasant to contemplate. Multiply this problem by the five to ten major components of each water system and a real nightmare could occur.

The need for standard design water systems is apparent. Yet, as was pointed out earlier, each water supply source will have different quality and quantity aspects. Nevertheless, it is possible to standardize many of the major components of the water systems. For successful operation, the rest area water systems must have a high degree of interchangeability of all elements. This may mean a limited degree of overdesign in the case of some installations.

In Iowa highly standardized water systems have been recommended and partially implemented, particularly the hydraulic components such as well pumps, booster pumps, and hydro-pneumatic tanks. This is further outlined in the Appendix and is a major item of design consideration.

A second item which should be obvious, but is neglected in many designs, is the provision of adequate space for the equipment needed. It will be impossible to properly operate and maintain the water system equipment if too little space is allowed.

BASIC DESIGN RECOMMENDATIONS

1. Because the rest area facilities are a water supply service to the public, the water supply capacity and water quality should be an important and early factor in planning the rest area facility. It is strongly urged that the exploration for the water source be completed before final site selection is made. Many operational problems can thus be prevented.
2. Owing to the expense involved with wells and water treatment processes, it would be desirable to use connections to municipal water supplies whenever possible.
3. To reduce the overall costs of the water systems and to increase the treatment process unit capacities to more desirable levels, the water systems of the rest area buildings, if in pairs as in Iowa, should be combined whenever possible.
4. Whenever the topography is favorable, elevated storage should be used to supply water pressure.
5. The water systems should be capable of supplying the estimated peak instantaneous water use rate for the required short durations.
6. Because the water use rate during the midday hours is often near the maximum hourly use rate, the essential elements of the system should be capable of sustained operation at or near the maximum hourly demand rate.
7. The capacity of the water supply source should be at least equal to the estimated maximum daily water use rate.
8. The maintenance and operational problems involved with the number of different water systems in each state is staggering to contemplate. As discussed earlier, a high degree of standardization of all elements is essential. This is often difficult to attain under the bid procedure limitations of public agencies, but the potential savings to the public far outweigh the bidding problems.
9. A second area of maintenance and operation to be considered is the personnel involved and management organization. The problems will be quite different from those previously encountered by highway personnel. A staff either within the existing organizations or separate, trained and educated in this area of engineering, may be needed for successful operation and maintenance of the rest area facilities.

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Appendix

IOWA REST AREA WATER SYSTEM SCHEMES

The following material is included to demonstrate that standardized designs are possible and feasible. The following water system schemes were recommended to the Iowa State Highway Commission and have been partially implemented, with other portions of the schemes to follow.

The main body of this paper has shown the development of the various demand rates for the Iowa rest area buildings. These are shown in Table 2. Most of the well water supplies in Iowa will require iron and manganese removal and softening. The development of the proposed water schemes is guided by these two treatment processes, if needed.

The following schemes are based on use of a hydro-pneumatic tank system to provide pressure; however, the schemes can be easily adapted for use of elevated storage where the topography allows.

Proposed Water System Schemes

The possible arrangement of the water systems is quite varied depending on well capacity available, treatment required (i. e., softening only or iron removal plus softening), and whether or not the water systems of the rest area building pairs can be combined. The following schemes take into account the wide variation possible in each of the three variables.

Scheme A-1—This scheme fits the following situation: (a) well capacity is 60 gpm or more; (b) softening is the only treatment required; and (c) each building water system is separate. In this scheme the well pump would discharge through the softening unit into two 360-gal hydro-pneumatic tanks. This is the simplest and most inexpensive system. However, it fits a situation found infrequently in Iowa, because most well waters require iron removal.

Scheme A-2—The following situation is applicable for this scheme: (a) well capacity is about 30 gpm; (b) softening is the only treatment needed; and (c) each building water

TABLE 2

ESTIMATED WATER DEMANDS FOR IOWA INTERSTATE SAFETY REST AREA BUILDINGS

Water Demands	Flow Rate (gpm)[a]	Flow Rate (gpd)[b]
Peak instantaneous	60	86,400
Maximum hourly	30	43,200
Maximum daily	15	21,600
Average daily	4	5,760

[a]Gallons per minute.
[b]Gallons per day.

system is separate. The system arrangement would have the well pump discharging through the softening unit into an intermediate storage of 1000-gal capacity. A 60-gpm booster pump then would take suction from the intermediate storage and discharge into one 360 gal hydro-pneumatic tank. As can be seen, this system is quite similar to Scheme A-1.

Scheme A-3—This scheme is identical to Scheme A-1 except that the well capacity is now about 15 gpm (the estimated maximum daily demand) and the intermediate storage volume required is 3600 gal.

Scheme A-4—This scheme is identical to Scheme A-1, except that the well capacity is 60 gpm and two 60-gpm booster pumps, one for each building, take suction from the 1000-gal intermediate storage. In other words, the two building water systems are combined.

Scheme A-5—In this scheme the two building water systems are again combined with a well capacity of 30 gpm and 7200 gal intermediate storage is required. The scheme is identical to Scheme A-4 except for the intermediate storage volume.

The A-series of schemes can be further compressed by providing an intermediate storage volume of 7200 gal minimum whenever intermediate storage is required. This allows development of only two basic plans when only softening of the water is required:

Plan A—In this plan, (a) well capacity is 60 gpm, (b) each building water system is separate, and (c) the well pump discharges through the softening unit into two 360-gal hydro-pneumatic tanks.

Plan AA—In this plan, (a) intermediate storage is 7200-gal capacity; (b) well capacity is 30 gpm and the sides are combined, or the well capacity is 15 gpm and the sides are separate (note that there is no advantage to having a well capacity greater than 30 gpm in this case); (c) the well pump discharges through the softening unit into the intermediate storage; (d) booster pumps of 60-gpm capacity, either one or two, are provided; and (e) the booster pumps take suction from the intermediate storage and discharge into 360-gal hydro-pneumatic tanks, one per side.

The following B-series of schemes can be organized into a similar pattern when iron and manganese removal is required in addition to softening. There is one additional restriction to be considered when iron and manganese removal is required. The additional limitation is that a minimum time period for filter run of about 3 hours is required to prevent the "flush-out" from the filters of the iron and manganese that has previously been removed. The flushing effect would occur under a frequent start-stop condition; thus there is no Scheme B-1 comparable to the Scheme A-1. Because of this limitation, the intermediate storage volume must be larger than the comparable A-series schemes.

Scheme B-2—In this scheme the following is applicable: (a) well capacity is 30 gpm; (b) iron, manganese, and softening treatment are needed; (c) each building water system is separate; (d) the booster pump is 60-gpm capacity; (e) intermediate storage volume is 7200 gal, dictated on minimum filter run length, assuming three-fourths of the storage volume is used in the operational cycle; (f) the well pump discharges through the iron and manganese removal unit into the softening unit and in turn into the intermediate storage; and (g) the booster pump takes suction from the intermediate storage and discharges into a 360-gal hydro-pneumatic tank.

Scheme B-3—This is identical to Scheme B-2 except that the well capacity is 15 gpm and the intermediate storage volume of 7200 gal is dictated by the need to meet the water demands and not by the minimum filter run lengths. Thus there is no advantage to having the well capacity greater than 15 gpm if the building water systems are separate and iron and manganese removal is required.

Scheme B-4—This is identical to Scheme B-2 except that the well capacity is 60 gpm and the building water systems are combined. The intermediate storage volume of 7200 gal is again dictated by the need to have a minimum 3-hour filter operational run.

Scheme B-5—This is identical to Scheme B-2 except that the building water systems are combined and the 7200-gal intermediate storage volume is dictated by the need to meet the water demand.

It is interesting and unusual that the B-series of schemes is essentially identical. As can be seen, there is no advantage to having the well capacity greater than 30 gpm if the building water systems are combined or greater than 15 gpm if separate. In fact, there is a disadvantage of larger capacity wells in that the treatment units would have to be larger and more expensive.

The B-series can be reduced to one plan which is very similar to Plan AA:

Plan B—In this plan, (a) intermediate storage volume is 7200 gal; (b) well capacity is 30 gpm and the water systems are combined, or the well capacity is 15 gpm and the water systems are separate; (c) the well pump discharges through the iron and manganese removal unit into the softening unit and then into the intermediate storage; (d) booster pumps of 60-gpm capacity, either one or two, are provided; and (e) the booster pumps take suction from the intermediate storage and discharge into 360-gal hydropneumatic tanks, one per side.

At this point, there are really only two basic plans, Plan A and Plan B, since Plan AA is only a special case of Plan B where iron and manganese removal is not required. These two plans will cover quite a wide variety of possible well capacities and water qualities. The advantages and disadvantages of these plans are summarized below. The plans are shown schematically in Figure 3.

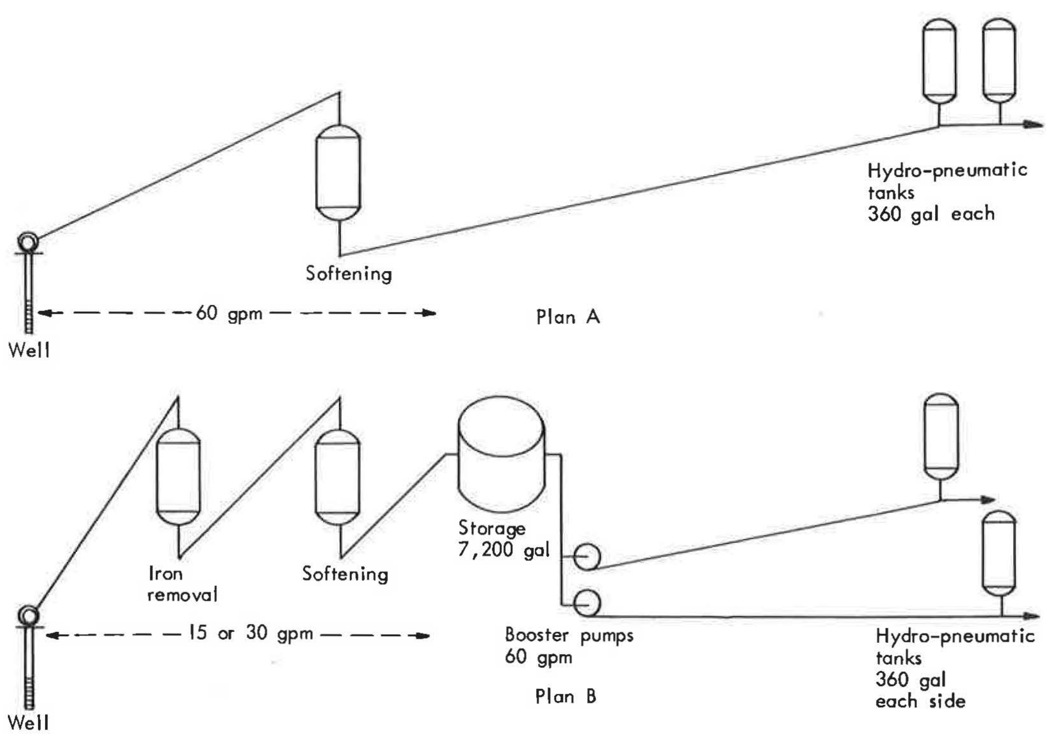

Figure 3. Basic water systems.

Advantages

1. Well pumps are used in only three capacities—60, 30, and 15 gpm; the majority will fall into the 30-gpm category.
2. The intermediate storage volume of 7200 gal is identical in all cases.
3. The booster pumps of 60-gpm capacity used will all be identical.
4. The hydro-pneumatic tanks will all be the same size, 360 gal, installed either singly or in pairs to meet the various situations.
5. A high degree of standardization can be achieved in well pumps, booster pumps, hydro-pneumatic tanks, treatment units, and controls.
6. When the building water systems are combined, the piping can be easily arranged to serve both sides from one booster pump, thus increasing the relability of the service.
7. Where the topography is favorable, the intermediate storage should be elevated storage, thus eliminating the booster pumps and the hydro-pneumatic tanks.
8. The use of intermediate storage provides a limited source of fire-fighting water.

Disadvantages

1. In the case where no iron removal is needed, the intermediate storage is oversized to some extent. However, the number of cases where iron removal will not be needed in Iowa will be in the minority. The relative cost of this oversized segment is quite low.
2. There may be occasions when chlorination could be required since the water will be exposed to the atmosphere before use and the potential for contamination is increased. With proper design, this need will be rather rare.